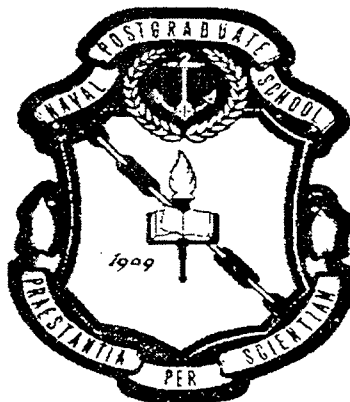


Naval Postgraduate School
Monterey, California 93943-5138

NPS-09-02-008



SUMMARY OF RESEARCH 2000



Department of Operations Research

**James D. Eagle
Chair**

**Kevin R. Wood
Associate Chair for Research**

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Prepared for: Naval Postgraduate School
Monterey, CA 93943-5000

20030108 111

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral David R. Ellison, USN
Superintendent


Richard Elster
Provost


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Reviewed by:

Released by:


Danielle Kuska
Director, Research Administration


David W. Netzer
Associate Provost and
Dean of Research

REPORT DOCUMENTATION PAGEForm approved
OMB No 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)**2. REPORT DATE**

December 2001

3. REPORT TYPE AND DATES COVERED

Summary Report, 1 October 1999-30 September 2000

4. TITLE AND SUBTITLE

Summary of Research 2000, Department of Operations Research

5. FUNDING**6. AUTHOR(S)**

Faculty of the Naval Postgraduate School

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)Naval Postgraduate School
Monterey, CA 93943-5000**8. PERFORMING ORGANIZATION
REPORT NUMBER**

NPS-09-02-008

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)Naval Postgraduate School
Monterey, CA 93943-5000**10. SPONSORING/MONITORING
AGENCY REPORT NUMBER****11. SUPPLEMENTARY NOTES**

The views expressed in this report are those of the authors and do not reflect the official policy or position of the Department of Defense or U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

A

13. ABSTRACT (Maximum 200 words.)

This report contains project summaries of the research projects in the Department of Operations Research. A list of recent publications is also included, which consists of conference presentations and publications, books, contributions to books, published journal papers, and technical reports. Thesis abstracts of students advised by faculty in the Department are also included.

14. SUBJECT TERMS**15. NUMBER OF
PAGES**

91

16. PRICE CODE**17. SECURITY CLASSIFICATION
OF REPORT**

Unclassified

**18. SECURITY CLASSIFICATION
OF THIS PAGE**

Unclassified

**19. SECURITY CLASSIFICATION
OF ABSTRACT**

Unclassified

**20. LIMITATION OF
ABSTRACT**

Unlimited

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Increase the combat effectiveness of the U.S. and allied forces and enhance the security of the U.S.A. through advanced education and research programs focused on the technical, analytical, and managerial tools needed to confront defense related challenges of the future.

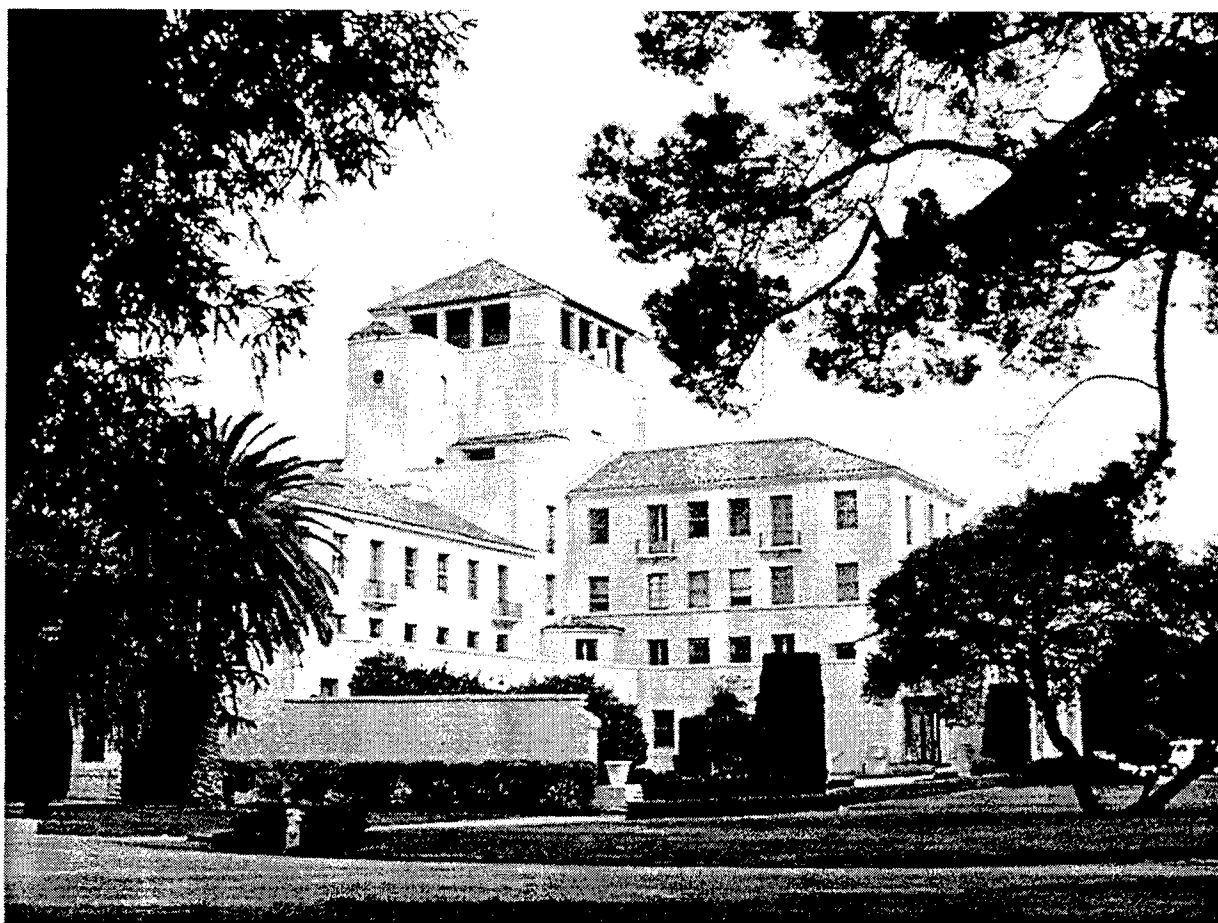


TABLE OF CONTENTS

Preface	xiii
Introduction	xv
Department Summary	3
Faculty Listing	5
Project Summaries	7
Large-Scale Optimization	7
An Architecture for Dynamic Planning Systems Using Loosely Coupled Components	8
Large-Scale Optimization	10
Logistics Modeling and Simulation	11
Maritime Operations Simulation Validation for Deepwater Acquisition	12
Chair of Manpower Modeling	12
Optimization Models for Installation Management	13
Optimally Scheduling EA-6B Depot Maintenance	14
Planning Capital Investments using Optimization	14
Optimizing Navy Program Planning	15
Planning Procurement and Deployment of Space and Missile Assets	16
Research in Joint Warfare Modeling and Simulation, Emphasizing Information Warfare Issues	17
Training and Research Support for Director, Operational Test and Evaluation	18
Exploratory AEA Modeling and Analysis, Using BAT/IW	19
Toxicity of Inhaled Jet Fuels: Rational Organ and Neurobehavioral Toxicity Assessment of a Complex Mixture	19
Development of a Research and Development Program and Methodology for the Government of Poland	19
Research in Applied Statistics: Capture-Recapture Methods and Measurement Error Models	20
Dual System Estimation in Census 2000: How Does Raking Differ from Smoothing?	20
Statistical Research in Joint Interoperability Testing of Theater Missile Defense Systems	21
Decomposition with Truncated Subproblems	21
Econometric Projection of Army Personnel Strength	22
Tree-Based Methods for Forecasting Retention Rates	22
Longitudinal Study of Training Deadtime	22
Methodology Research in Wargaming and Analysis	23
Land Attack Predesignation (LAP)	23
Generalized Network Enlisted Component of the Active Army Strength Forecaster	24
Optimization Modeling in Support of Tanker Requirements Study for 2005	25
Sea Based Logistics	25
Economic Benefit of Naval Forward Presence	26
Support and Review of the Modeling of Ground Combat in Integrated Theater Engagement Model	27
Joint Combat Capability	27
Navy Airlift	28
Large-Scale Mixed Integer Programming	28
Summer Program in Operations Research Technology	29
Support for the Center for Operations Research, National Security Agency	29
Publications and Presentations	31
Thesis Abstracts	37
The K-Group Maximum-Flow Network-Interdiction Problem	39
Analysis of the Deterioration Rate of Ship Handling Proficiency of Surface Warfare Officers on Shore Duty	39
An Analytical Comparison of Human Factor Maintenance Related Part Failures for Naval Reserve Fleet Logistics Support Wing	40
A Cost Model for Estimating Operating and Support Costs for United States Navy (Nuclear) Submarines	40

TABLE OF CONTENTS

An Intelligent Agent Simulation of Shipboard Damage Control	41
The Relationship between a Submarine's Maximum Speed and Its Evasive Capability	41
A Fast Heuristic for Tomahawk Land-Attack Predesignation.....	42
Screen Dispositions of Naval Task Forces Against Anti-Ship Missiles	42
Optimally Scheduling EA-6B Depot Maintenance and Aircraft Modification Kit Procurement	43
Optimization of United States Marine Corps Officer Career Path Selection	43
Solving Dynamic Battlespace Movement Problems Using Dynamic Distributed Computer Networks	44
Agent Based Simulation as an Exploratory Tool in the Study of the Human Dimension of Combat	44
Case Study of the United States Marine Corps Advanced Amphibious Assault Vehicle (AAAV) Program Test and Evaluation Strategy	45
A Multivariate Time Series Analysis of U.S. Army Recruiting	45
An Analysis of Purchase Card Reconciliation Times.....	46
Service Level Optimization for the Marine Corps Institute	46
Cost and Operational Effectiveness Analysis of Alternative Force Structures for Fulfillment of the United States Marine Corps Operational Support Airlift and Search and Rescue Missions.....	47
Using Neural Networks within the Leaves of a Classification Tree.....	47
An Analysis of the Impact of Fully Funded Graduate Education on the Retention of Naval Officers.....	48
Human Factors Analysis of Fiscal Year 90 to 97 Rotary Wing and TACAIR Flight Mishaps	48
Assigning Unmanned Undersea Vehicles to Mine Detection Operations	49
Campaign Analysis of a NATO Ground Forces Campaign in Kosovo	49
Comparison Study of JANUS and HLA Warrior	50
Assessment of Shallow Water Influence Minesweeping System (SWIMS) Implementation Utilizing CH-60.....	50
Design and Analysis of a Shipboard Visual Navigation Aid for Vessels in Formation	51
Who Responds and How Long Does it Take: Assigning Fire Station Areas of Responsibility	51
Planning Capital Investments in Navy Forces.....	52
Protecting the Force: Application of Statistical Process Control for Force Protection in Bosnia.....	52
An Evaluation of Sea-Based Sustainment of Forces	53
Age Replacement Policies in Multiple Time Scales.....	53
Modeling and Analysis of Human Error in Naval Aviation Maintenance-Related Mishaps	54
Enumerating Near-Minimum Cuts in a Network	54
Fitting Firepower Score Models to the Battle of Kursk Data	55
Minimizing Time Awaiting Training for Graduates of the Basic School	55
Improving Nominal Reliability Confidence Bounds Using Coverage Probabilities Generated through Monte Carlo Simulation and Illustrated by Monte Carlo Simulation	56
An Evaluation of the Aviation Maintenance Climate Assessment Survey (MCAS) Applied to the 3rd Marine Air Wing.....	56
Fleet Support Officer Fleet Training (FSOFT): Should a Sea Tour be a Requirement?	57
Human Factors Analysis of U.S. Navy Afloat Hazardous Material Mishaps.....	57
A Heuristic for Land-Attack Predesignation	58
Optimization of Procurement Scheduling for Major Defense Acquisition Programs	58
Sensitivity Analysis of the Topology of Classification Trees	59
Advanced Naval Surface Fire Support Weapon Employment Against Mobile Targets.....	59
Planning Flight Training for the Transition to the V-22 Osprey	60

TABLE OF CONTENTS

Deterministic and Stochastic Models of Biological Attacks on Seaports of Debarkation during a Major Theater War	60
Graphic User Interface Design for Mapping, Information, Display, and Analysis Systems	61
Thorn: A Study in Designing a Usable Interface for a Geo-Referenced Discrete Event Simulation	61
The Potential Impact of Hyperspectral Imagery on Amphibious Warfare Planning	62
An Evaluation of the Hydra-7 Countermine Weapon System	62
An Exploratory Analysis of the Military Value of Information and Force	63
Ranger Air Load Planner	63
Exploratory Model Analysis of the Space Based Infrared System (SBIRS) Low Global Scheduler Problem	64
Calculation of Barrier Search Probability of Detection for Arbitrary Search Tracks	64
A Comparison of Output from the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) Model with Surface Velocity	65
Data from Drifting Buoys in the North Atlantic Ocean	65
Optimizing Procurement of Special Operations Weapons and Equipment	65
Determinants of Flight Training Performance: An Analysis of the Impact of Undergraduate Academic Background	66
Statistical Analysis of the Naval Inventory Control Point Repair Turn-Around Time Forecast Model	66
Modeling and Simulation Support for the Operational Test and Evaluation of a Tactical Airborne Reconnaissance System	67
Predicting Casualties in Simulation Models ("Cosage") Using Discrete-Time Analytical Models	67
Optimal Positioning of Naval Precision Guided Munitions	68
Aim-7 Sparrow MK-58 Rocket Motor Reliability and Life Data Analysis	68
The Flaming Datum Problem with Varying Speed	69
An Event-Step Simulation for Evaluating DD21 System Effectiveness	69
Evaluating Demographic Item Relationships with Survey Responses on the Maintenance Climate Assessment Survey (MCAS)	70
The Use of Advanced Warfighting Experiments to Support Acquisition Decisions	70
Fitting Lanchester and Other Equations to the Battle of Kursk Data	71
A Simulation of the Joint Tactical Radio System Bandwidth Requirements to Support Marine Corps Ship-to-Objective Maneuver in 2015	71
Dynamic Exploration of Helicopter Reconnaissance through Agent-Based Modeling	72
Optimal Allocation of Selected T-Series Advanced Base Functional Component Equipment Packages	72
Statistical Monitoring of Police Force for Rapid Detection of Changes in Frequency	73
Agent-Based Simulation of Military Operations Other Than War Small Unit Combat	73
An Infinite Horizon Army Manpower Planning Model	74
Initial Distribution List	75

PREFACE

Research at the Naval Postgraduate School is carried out by faculty in the four graduate schools (School of International Graduate Studies, Graduate School of Operations and Information Sciences, Graduate School of Engineering and Applied Sciences, and Graduate School of Business and Public Policy) and three Research Institutes (The Modeling, Virtual Environments, and Simulation (MOVES) Institute, Institute for Information Superiority and Innovation (I2SI), and Institute for Defense System Engineering and Analysis (IDSEA). This volume contains research summaries for the projects undertaken by faculty in the Department of Operations Research during 2000. The summary also contains thesis abstracts for those students advised by Operations Research faculty during 2000.

Questions about particular projects may be directed to the faculty Principal Investigator listed, the Department Chair, or the Department Associate Chair for Research. Questions may also be directed to the Office of the Associate Provost and Dean of Research. General questions about the Naval Postgraduate School Research Program should be directed to the Office of the Associate Provost and Dean of Research at (831) 656-2099 (voice) or research@nps.navy.mil (e-mail). Additional information is also available at the RESEARCH AT NPS website, <http://web.nps.navy.mil/~code09/>

Additional published information on the Naval Postgraduate School Research Program can be found in:

- *Compilation of Theses Abstracts:* A quarterly publication containing the abstracts of all unclassified theses by Naval Postgraduate School students.
- *Naval Postgraduate School Research:* A tri-annual (February, June, October) newsletter highlighting Naval Postgraduate School faculty and student research.
- *Summary of Research:* An annual publication containing research summaries for projects undertaken by the faculty of the Naval Postgraduate School.

This publication and those mentioned above can be found on-line at:
<http://web.nps.navy.mil/~code09/publications.html>.

INTRODUCTION

The research program at the Naval Postgraduate School exists to support the graduate education of our students. It does so by providing military relevant thesis topics that address issues from the current needs of the Fleet and Joint Forces to the science and technology that is required to sustain the long-term superiority of the Navy/DoD. It keeps our faculty current on Navy/DoD issues, to maintain the content of the upper division courses at the cutting edge of their disciplines. At the same time, the students and faculty together provide a very unique capability within the DoD for addressing warfighting problems. Our officers must be able to think innovatively and have the knowledge and skills that will let them apply technologies that are being rapidly developed in both the commercial and military sectors. Their unique knowledge of the operational Navy, when combined with a challenging thesis project that requires them to apply their focused graduate education, is one of the most effective methods for both solving Fleet problems and instilling the life-long capability for applying basic principles to the creative solution of complex problems.

The research program at the Naval Postgraduate School consists of both reimbursable (sponsored) and institutionally funded research. The research varies from very fundamental to very applied, from unclassified to all levels of classification.

- **Reimbursable (Sponsored) Program:** This program includes those projects externally funded on the basis of proposals submitted to outside sponsors by the School's faculty. These funds allow the faculty to interact closely with RDT&E program managers and high-level policymakers throughout the Navy, DoD, and other government agencies as well as with the private sector in defense-related technologies. The sponsored program utilizes Cooperative Research and Development Agreements (CRADAs) with private industry, participates in consortia with government laboratories and universities, provides off-campus courses either on-site at the recipient command, by VTC, or web-based, and provides short courses for technology updates.
- **Naval Postgraduate School Institutionally Funded Research (NIFR) Program:** The institutionally funded research program has several purposes: (1) to provide the initial support required for new faculty to establish a Navy/DoD relevant research area, (2) to provide support for major new initiatives that address near-term Fleet and OPNAV needs, (3) to enhance productive research that is reimbursably sponsored, and (4) to cost-share the support of a strong post-doctoral program.

In 2000, the level of research effort overall at the Naval Postgraduate School was 137 faculty work years and exceeded \$43 million. The reimbursable program has grown steadily to provide the faculty and staff support that is required to sustain a strong and viable graduate school in times of reduced budgets. In FY2000, over 93% of the research program was externally supported. A profile of the sponsorship of the Naval Postgraduate School Research Program in FY2000 is provided in Figure 1.

INTRODUCTION

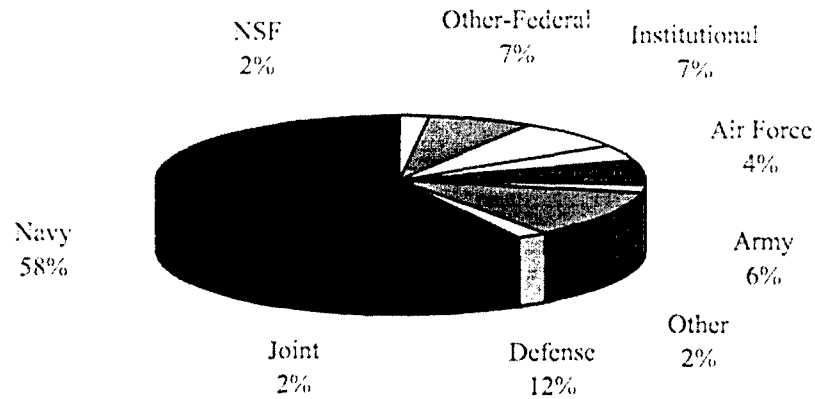


Figure 1. Profile of NPS Research and Sponsored Programs (\$43M)

The Office of Naval Research is the largest Navy external sponsor. The Naval Postgraduate School also supports the Systems Commands, Warfare Centers, Navy Labs and other Navy agencies. A profile of external Navy sponsorship for FY2000 is provided in Figure 2.

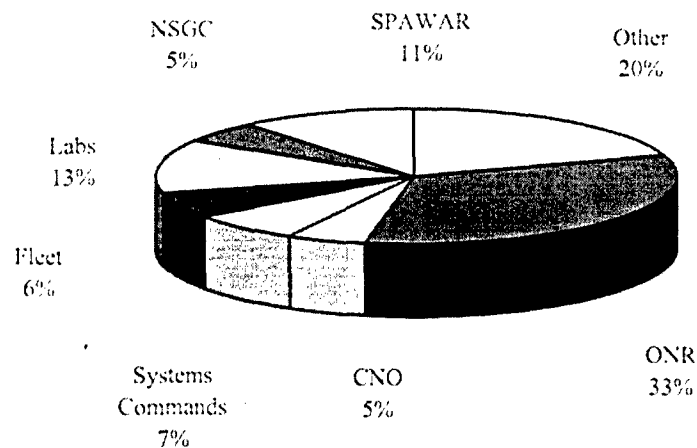


Figure 2. Navy External Sponsors of NPS Research and Sponsored Programs (\$25M)

These are both challenging and exciting times at the Naval Postgraduate School and the research program exists to help ensure that we remain unique in our ability to provide education for the warfighter.

DAVID W. NETZER
Associate Provost and Dean of Research

December 2001

**DEPARTMENT OF
OPERATIONS RESEARCH**

**JAMES EAGLE
CHAIR**

DEPARTMENT SUMMARY

OVERVIEW:

The Naval Postgraduate School Operations Research (OR) program is a world-class curriculum designed to teach students the science of helping people and organizations make better decisions.

This science is necessary in today's increasingly complex operating environment in which officers and managers must respond quickly to a vast array of demands while also weighing the options and consequences of each into his or her final decision. OR offers a scientific approach through the use of many tools and techniques in order to assist an individual in his or her decision making process.

The military specifically uses OR at the strategic, operational, and tactical levels. OR applications cover the gamut of military activities including: National policy analysis, resource allocation, force composition and modernization, logistics, human resources, battle planning, flight operations scheduling, intelligence, command and control, weapon selection, engagement tactics, maintenance and replenishment, and search and rescue.

The Department of Operations Research mission is:

- To educate analysts who are fully capable of conducting independent analytical studies of military problems, and have an educational basis for continued learning and development.
- To provide the United States government and our allies with military officers who have a comprehensive knowledge of military operations research, and who can perform and manage quantitative analysis of operational and other Defense problems.
- To provide operations research and general analysis support to DoD.
- To develop and maintain a world-class research program in operations research and related areas.

CURRICULA SERVED:

- Operations Analysis
- Operations Logistics
- Undersea Warfare
- Joint C4I Systems
- Applied Mathematics
- Management

DEGREES GRANTED:

- Master of Science in Operations Research
- Master of Science in Applied Science
- Doctor of Philosophy

RESEARCH THRUSTS:

- Probability and Stochastic Processes
- Statistics and Data Analysis
- Optimization
- Human Systems Integration
- Simulation and War Gaming
- Search, Detection and Evasion
- Interactive, Distributed Information Technology

RESEARCH CHAIRS:

- Chair for Manpower Modeling
- Chair of Applied Systems Analysis
- Chair of Tactical Analysis

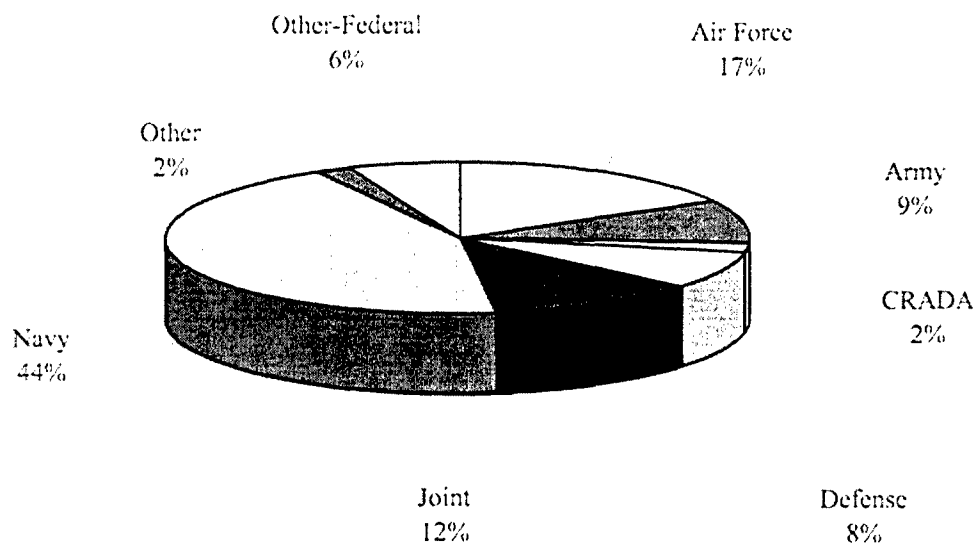
DEPARTMENT SUMMARY

RESEARCH FACILITIES:

- Secure Computing and Simulation Lab (WARLAB)
- Optimization Lab
- Human Systems Integration Laboratory (HISL)

RESEARCH PROGRAM-FY2000:

The Naval Postgraduate School's research program exceeded \$43 million in FY2000. Over 93% of the Naval Postgraduate School Research Program is externally funded. A profile of the external research sponsors for the Department of Operations Research is provided below along with the size of the FY2000 externally funded program.



Size of Program: \$1,826K

FACULTY LISTING

Eagle, James D.
Professor and
Chair
OR/Er
656-2654
jeagle@nps.navy.mil

Wood, R. Kevin
Professor and
Associate Chair for Research
OR/Wd
656-2523
kwood@nps.navy.mil

Anderson, Timothy, LCDR, USN
Military Instructor
OR/At
656-3583
tpanderson@nps.navy.mil

Gaver, Donald P., Jr.
Distinguished Professor
OR/Gv
656-2605
dgaver@nps.navy.mil

Lucas, Thomas W.
Associate Professor
OR/Lt
656-3039
twlucas@nps.navy.mil

Boensel, Matthew G., CDR, USN
Military Instructor
OR/Bm
656-3489
mgboense@nps.navy.mil

Hoivik, Thomas H.
Senior Lecturer
OR/Ho
656-2040
thhoivik@nps.navy.mil

Maher, Kevin J., CDR, USN
Military Instructor
OR/Mk
656-2691
kjmaher@nps.navy.mil

Bradley, Gordon H.
Professor
OR/Bz
656-2359
gbradley@nps.navy.mil

Jacobs, Patricia A.
Professor
OR/Jc
656-2258
pjacobs@nps.navy.mil

Miller, Nita
Visiting Assistant Professor
OR/Mn
656-2281
nlmiller@nps.navy.mil

Brown, Gerald G.
Professor
OR/Bw
656-2140
gbrown@nps.navy.mil

Kemple, William G.
Associate Professor
OR/Ke
656-3309
kemple@nps.navy.mil

Parker, Joel R., LTC, USA
Military Instructor
OR/Jp
656-2636
tpanderson@nps.navy.mil

Buss, Arnie
Assistant Professor
OR/Bu
656-3259
abuss@nps.navy.mil

Koyak, Robert A.
Assistant Professor
OR/Kr
656-2688
rakoyak@nps.navy.mil

Paulo, Eugene P., LTC, USA
Military Instructor
OR/O1
656-3452
eppaulo@nps.navy.mil

Buttrey, Samuel E.
Assistant Professor
OR/Sb
656-3035
buttrey@nps.navy.mil

Kress, Moshe
Visiting Professor
OR/Ko
656-3647
mkress@nps.navy.mil

Read, Robert R.
Professor
OR/Re
656-2382
rread@nps.navy.mil

Dell, Robert
Associate Professor
OR/De
656-2853
dell@nps.navy.mil

Lawphongpanich, Siriphong
Associate Professor
OR/Lp
656-2106
slawphon@nps.navy.mil

Rosenthal, Richard E.
Professor
OR/R1
656-2795
rosenthal@nps.navy.mil

FACULTY LISTING

Rowe, Anton
Research Assistant Professor
OR/Ar
656-2385
arowe@nps.navy.mil

Salmeron, Javier
Research Assistant Professor
OR/Sa
656-2779
jsalmero@nps.navy.mil

Sanchez, Paul
Visiting Assistant Professor
OR/Sp
656-3053
pjsanche@nps.navy.mil

Sanchez, Susan M.
Professor
OR/Su
656-2780
smsanche@nps.navy.mil

Schrady, David A.
Distinguished Professor
OR/So
656-2801
dschrady@nps.navy.mil

Taylor, James G.
Professor
OR/Tw
656-2683
jtaylor@nps.navy.mil

Washburn, Alan R.
Professor
OR/Ws
656-3127
awashburn@nps.navy.mil

Whitaker, Lyn R.
Associate Professor
OR/Wh
656-3482
lwhitaker@nps.navy.mil

Widdis, Daniel B., LCDR, USN
Military Instructor
OR/Wi
656-3040
dbwiddis@nps.navy.mil

Williams, Laura M.
Research Assistant Professor
OR
656-4140
lmwilliams@nps.navy.mil

PROJECT SUMMARIES

LARGE-SCALE OPTIMIZATION

Gordon H. Bradley, Professor

Gerald G. Brown, Professor

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Office of Naval Research and Naval Postgraduate School

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and develop graph and network algorithms for dynamic map-based military planning applications. This is a continuing research project.

SUMMARY: One part of this research designed and developed a toolkit of methods to quickly construct graph and network algorithms. The algorithms were integrated into a dynamic map-based military planning system that operates over heterogeneous computer networks. The system can download algorithms over a computer network and execute them to analyze operations. The design allows algorithms to be easily added to the planning system. Another part of this research developed new Monte Carlo methods for evaluating the accuracy of solutions to stochastic programming models. We have also developed a new class of simplicial penalties applicable in lieu of polyhedral cuts to encourage admissible integer polyhedral solutions.

PUBLICATIONS:

Appleget, J. and Wood, K., 2000, "Explicit-Constraint Branching for Solving Mixed-Integer Programs," *Computing Tools for Modeling, Optimization and Simulation*, M. Laguna and J.L. González-Velarde, editors, Kluwer Academic Publishers, Boston, pp. 243-261.

Brown, G., Dell, R., and Olson, M., 2000, "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," *Operations Research Letters*, 26, 117-126.

Israeli, E., and Wood, K., "Shortest-Path Network Interdiction," in review.

PRESENTATIONS:

Appleget, J. and Wood, R.K., "Explicit-Constraint Branching for Solving Mixed-Integer Programs," 7th INFORMS Computing Society Conference, Cancun, Mexico, 5-7 January 2000.

Bradley, G., Buss, A., Parker, J., and Sanchez, P., "Loosely Coupled Components Laboratory - Overview and Open House," Department of Operations Research Seminar, Monterey, CA, 27 January 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," OASD SO/LIC Special Operations C4I R&D Workshop, McLean, VA, 19-21 July 2000.

Bradley, G. and Buss, A., "Architecture for Dynamic Planning Systems Using Loosely Coupled Components," IFIP WORKING GROUP 7.6 Workshop on Virtual Environments for Advanced Modeling, Monterey, CA, 2-4 August 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," Inter-service Mission Planning Working Group Meeting (IMPWG), Huntsville, AL, 24-25 October 2000.

Morton, D., Salmeron, J., and Wood, R.K., "New Decomposition-Based Techniques for Solving Two-Stage Stochastic Programs," International Symposium on Mathematical Programming, Atlanta, GA, 7-11 August 2000.

Salmeron, J. and Wood, K., "Solving Stochastic Network Interdiction Problems," INFORMS National Meeting, San Antonio, TX, 5-8 November 2000.

PROJECT SUMMARIES

Salmeron, J. and Wood, R.K., "A Sampling-Based Cutting Plane Method for Stochastic Programs," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Akgun, I. and Wood, R.K., "Multi-Unit Network Interdiction," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Wood, R.K., "Network Interdiction and Eavesdropping," Colloquium in Engineering Economic Systems and Operations Research, Stanford University, Palo Alto, CA, 9 May 2000.

Wood, R.K., "Network Interdiction and Eavesdropping," National Security Agency, Operations Research and Management Science Symposium, 11 April 2000.

THESES DIRECTED:

Balcioglu, A., "An Algorithm for Enumerating The Near-Minimum Weight s-t Cuts of a Graph," Masters Thesis, Naval Postgraduate School, March 2000.

Loh, Long Piao, "Deterministic and Stochastic Models of Biological Attacks on Seaports of Debarkation During a Major Theater War," Masters Thesis, Naval Postgraduate School, September 2000.

Akgun, I., "The K-Group Maximum-Flow Network-Interdiction Problem," Masters Thesis, Naval Postgraduate School, June 2000.

Bradford, R.D., III, "Solving Dynamic Battlespace Movement Problems Using Dynamic Distributed Computer Networks," Masters Thesis, Naval Postgraduate School, June 2000.

Lowell, J.P., "Graphic User Interface Design for Mapping, Information, Display, and Analysis Systems," Masters Thesis, Naval Postgraduate School, June 2000.

Moore M.A., III, "Ranger Air Load Planner," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Dynamic Planning

AN ARCHITECTURE FOR DYNAMIC PLANNING SYSTEMS USING LOOSELY COUPLED COMPONENTS

Gordon H. Bradley, Professor

Arnold H. Buss, Assistant Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Design and develop architecture for dynamic map-based military planning applications using new platform-independent software technology. This is a continuing research project.

SUMMARY: The research has designed and developed a "loosely coupled components" architecture that has been demonstrated by constructing a map-based planning system for dynamic military planning. The architecture coordinates a collection of components that operate over heterogeneous computer networks. The system accesses and displays data, maps, overlays, algorithms, and other information. The components perform tasks such as: displaying maps, satellite images, and overlays; accessing, entering, and modifying data; constructing and displaying models of military operations; and accessing and executing algorithms to analyze operations. The design allows systems to be easily extended by adding addition components.

PROJECT SUMMARIES

PRESENTATIONS:

Bradley, G., Buss, A., Parker, J., and Sanchez, P., "Loosely Coupled Components Laboratory - Overview and Open House," Department of Operations Research Seminar, Monterey, CA, 27 January 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," OASD SO/LIC Special Operations C4I R&D Workshop, McLean, VA, 19-21 July 2000.

Bradley, G. and Buss, A., "Architecture for Dynamic Planning Systems Using Loosely Coupled Components," IFIP WORKING GROUP 7.6 Workshop on Virtual Environments for Advanced Modeling, Monterey, CA, August 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," Inter-service Mission Planning Working Group Meeting (IMPWG), Huntsville, AL, 24-25 October 2000.

Bradley, G. and Buss, A., "Loosely Coupled Components Project: Map-Based Military Planning," The Third International Meeting of the INFORMS Military Application Society, San Antonio, TX, 5-8 November 2000.

THESES DIRECTED:

Armo, K.R., "The Relationship Between a Submarine's Maximum Speed and Its Evasive Capability," Masters Thesis, Naval Postgraduate School, June 2000.

Aydin, E., "Screen Dispositions of Naval Task Forces Against Anti-ship Missiles," Masters Thesis, Naval Postgraduate School, March 2000.

Bradford, R.D., III, "Solving Dynamic Battlespace Movement Problems Using Dynamic Distributed Computer Networks," Masters Thesis, Naval Postgraduate School, June 2000.

Lowell, J.P., "Graphic User Interface Design for Mapping, Information, Display, and Analysis Systems," Masters Thesis, Naval Postgraduate School, June 2000.

Mack, P.V., "THORN: A Study in Designing a Usable Interface for a Geo-Referenced Discrete Event Simulation," Masters Thesis, Naval Postgraduate School, September 2000.

Moore M.A., III, "Ranger Air Load Planner," Masters Thesis, Naval Postgraduate School, June 2000.

Turner, T.E., "A Simulation of the Joint Tactical Radio System Bandwidth Requirements to Support Marine Corps Ship to Objective Maneuver in 2015," Masters Thesis, Naval Postgraduate School, September 2000.

Woodaman, R.F.A., "Agent-Based Simulation of Military Operations Other Than War Small Unit Combat," Masters Thesis, Naval Postgraduate School, September 2000.

OTHER:

Bradley, G.H. and Buss, A., SOFLCC: A system to support real-time and near real-time decision-making for Special Operations Forces using network models based on the Loosely Coupled Components Architecture (LCCA).

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Computing and Software, Modeling and Simulation, Other (Decision Support Systems)

KEYWORDS: Dynamic Planning, Loosely Coupled Components, Platform Independent Software, Java

PROJECT SUMMARIES

LARGE-SCALE OPTIMIZATION

Gerald G. Brown, Professor

R. Kevin Wood, Professor

Department of Operations Research

Sponsor: Air Force Office of Scientific Research

OBJECTIVE: Use large-scale mathematical programming techniques to solve deterministic and stochastic extensions of important combinatorial optimization models and mathematical programs. Develop extensions of network-interdiction techniques to solve more general system interdiction models.

SUMMARY: We have devised and implemented a joint theater combat model to address a long-standing problem faced by the Joint Staff (J8): "How do you integrate the Air Force optimization view of air-to-ground combat with the Army simulation view of ground battle?" Our proof prototype, called the Fast Theater Model (FATHM), fights a full theater war with alternating air optimizations and Lanchester ground combat simulations. Full-scale war plans are optimized in about twenty minutes. Network interdiction models and solution techniques have been extended to solve system interdiction and defense models where a system is modeled as a linear or integer program, or as another interdiction model. The last generalization allows us to solve a tri-level system defense model where a network or other system is optimally hardened against attack. Extensions to stochastic interdiction models have been developed.

PUBLICATIONS:

Appleget, J. and Wood, K., 2000, "Explicit-Constraint Branching for Solving Mixed-Integer Programs," in *Computing Tools for Modeling, Optimization and Simulation*, M. Laguna and J.L. González-Velarde, eds., Kluwer Academic Publishers, Boston, pp. 243-261.

Brown, G., Dell, R., and Olson, M., 2000, "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," *Operations Research Letters*, 26, pp. 117-126.

Israeli, E., and Wood, K., "Shortest-Path Network Interdiction," in review.

Brown, G.G. and Washburn, A., Dell, R.F., Giddings, A., and Rosenthal, R., "An Integer-Linear Program to Plan Procurement" and "The Fast Theater Model (FATHM)," Naval Postgraduate School Project Report, NPS-OR-01-002-PR, October 2000.

Newman, A.M. and Brown, G.G., "Deployment of Space and Missile Assets," Naval Postgraduate School Technical Report, NPS-OR-00-005, April 2000.

PRESENTATIONS:

Akgun, I. and Wood, R.K., "Multi-Unit Network Interdiction," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Appleget, J. and Wood, R.K., "Explicit-Constraint Branching for Solving Mixed-Integer Programs," 7th INFORMS Computing Society Conference, Cancun, Mexico, 5-7 January 2000.

Morton, D., Salmeron, J., and Wood, R.K., "New Decomposition-Based Techniques for Solving Two-Stage Stochastic Programs," International Symposium on Mathematical Programming, Atlanta, GA, 7-11 August 2000.

Salmeron, J. and Wood, R.K., "A Sampling-Based Cutting Plane Method for Stochastic Programs," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Salmeron, J. and Wood, R.K., "Solving Stochastic Network Interdiction Problems," INFORMS National Meeting, San Antonio, TX, 5-8 November 2000.

PROJECT SUMMARIES

Wood, R.K., "Network Interdiction and Eavesdropping," Colloquium in Engineering Economic Systems and Operations Research, Stanford University, Palo Alto, CA, 9 May 2000.

Wood, R.K., "Network Interdiction and Eavesdropping," National Security Agency, Operations Research and Management Science Symposium, 11 April 2000.

THESES DIRECTED:

Akgun, I., "The K-Group Maximum-Flow Network-Interdiction Problem," Masters Thesis, Naval Postgraduate School, March 2000.

Arnold, A., "A Fast Heuristic for Tomahawk Land-Attack Predesignation," Masters Thesis, Naval Postgraduate School, June 2000.

Balcioglu, Ahmet, "An Algorithm for Enumerating the Near-Minimum Weight s-t Cuts of a Graph," Masters Thesis, Naval Postgraduate School, December 2000.

Baran, N., "Optimizing Procurement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2000.

Gibbons, M., "Enumerating Near-Minimum Cuts in a Network," Masters Thesis, Naval Postgraduate School, June 2000.

Liebe, R.M., "Planning Flight Training for the Transition to the V-22 Osprey," Masters Thesis, Naval Postgraduate School, September 2000.

Loh, Long Piao, "Deterministic and Stochastic Models of Biological Attacks on Seaports of Debarkation During a Major Theater War," Masters Thesis, Naval Postgraduate School, September 2000.

Moore, M.A., "Ranger Air Load Planner," Masters Thesis, Naval Postgraduate School, June 2000.

Pfarrer, M., "Optimizing Procurement of Special Operations Weapons and Equipment," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software, Other (Optimization, Decision Support Systems)

KEYWORDS: Integer Programming, Stochastic Programming, Network Interdiction

LOGISTICS MODELING AND SIMULATION

Arnold H. Buss, Assistant Professor

Department of Operations Research

Sponsor: Lockheed Martin – DD21 Blue Team

OBJECTIVE: Support and theoretical development for DD21 Readiness (Ao and Ai) Modeling and Analysis This is a detailed Logistics Reliability, Availability and Maintainability (RAM) Analysis based on Baselines 4 and 5 with known parameters to the sub-system and possibly segment level (not to LRU which will not be available until Baseline 6).

SUMMARY: The object-oriented, discrete-event simulation developed in this study evaluates the rate at which DD21's weapon systems can complete arriving land attack tasks with its Advanced Gun and Vertical Launch Systems. The DD21 simulation measures how sensitive this completion rate is to discovery/localization of individual component failures. The DD21 simulation also provides for two distinct methods of scoring task completion: no scoring for a task completed after its intended time, and

PROJECT SUMMARIES

partial scoring for such a task. The primary output from the simulation is the system effectiveness of DD21 over the course of its mission. Another output is the mean number of tasks lost due to failure for each weapon system.

THESIS DIRECTED:

Snyder, W.H., III, "An Event-Step Simulation for Evaluating DD21 System Effectiveness," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Logistics Modeling, Discrete Event Simulation, Sensitivity Analysis, Reliability, Availability, Maintainability, Readiness

MARITIME OPERATIONS SIMULATION VALIDATION FOR DEEPWATER ACQUISITION

Arnold H. Buss, Assistant Professor

Thomas Halwachs, Senior Lecturer

Department of Operations Research

Sponsor: U. S. Coast Guard Research and Development Center

OBJECTIVE: Conduct a Verification, Validation, and Applicability Assessment for MarOpsSim, a simulation model under development for the United States Coast Guard to support the new Deepwater Acquisition process.

SUMMARY: MarOpsSim is a multi-mission discrete-event simulation model currently being developed for the United States Coast Guard to support performance assessment and analysis alternatives. In accordance with sound principles of Modeling and Simulation development, Verification and Validation (V&V) of MarOpsSim was performed, and a review of its domain of applicability needs conducted, prior to its acceptance for use in the Deepwater Acquisition process. The V&V effort included: validation of basic simulation mechanisms, including event management, random variate generation, and scripting; validation of basic platform modeling, including movement and sensing; validation of environmental modeling; validation of database and input models; verification of scripts and input configurations; and recommendations for possible model improvements. This constituted Phase I of the V&V effort for MarOpsSim. Phase II is to be completed in FY 01.

PUBLICATION:

Buss, A.H. and Halwachs, T., "Core Validation for Maritime Operations Simulation (MarOpsSim)," Naval Postgraduate School Technical Report, NPS-OR-00-003, 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Discrete Event Simulation, Coast Guard, Deepwater Acquisition, Movement and Sensing Algorithms, Environmental Modeling, Verification and Validation

CHAIR OF MANPOWER MODELING

Samuel Buttrey, Assistant Professor

Department of Operations Research

Sponsor: Office of Army Deputy Chief of Staff, Personnel

OBJECTIVE: Support ODCSPER in its redesign of manpower models; provide short- and long-term statistical consulting to ODCSPER and contractors on manpower issues; support Army thesis student research and advise theses as appropriate; act as liaison between ODCSPER and NPS faculty undertaking reimbursable research for ODCSPER.

PROJECT SUMMARIES

SUMMARY: ODCSPER continues to upgrade its manpower planning and analysis systems. I have acted as a statistical consultant on design issues, like the division of first-term soldiers into characteristic groups that tend to be homogeneous with respect to attrition. The determination of the number and type of these groups has a large effect on the performance of network flow models proposed and implemented by the contractor. Other consulting issues have been handled as necessary. I advised the thesis of Captain Burger and supported that of Major Yamada.

THESES DIRECTED:

Burger, E.C., "A Multivariate Time Series Analysis of U.S. Army Recruiting," Masters Thesis, Naval Postgraduate School, June 2000.

Yamada, W.S., "An Infinite Horizon Army Manpower Planning Model," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Retention, Force Forecasting

OPTIMIZATION MODELS FOR INSTALLATION MANAGEMENT

Robert F. Dell, Associate Professor

Department of Operations Research

**Sponsors: United States Army Base Realignment and Closure Office and
Naval Postgraduate School**

OBJECTIVE: Develop optimization models to assist with installation management.

SUMMARY: The investigator is providing research, support, and development of optimization models to assist the Army's Base Realignment and Closure Office (BRACO). The integer-linear program BAEC (Budget Allocation for Environmental Cleanup) was the primary 2000 development effort. BRACO used BAEC to help plan \$620 million in environmental cleanup at 649 sites on 39 current and former Army installations. The integer-linear program OSAF (Optimal Stationing of Army Forces) was also started with the Center for Army Analysis to help answer a QDR (Quadrennial Defense Review) issue, "What are the infrastructure requirements to support the Army of the future?"

PUBLICATION:

Brown, G.G., Dell, R.F., and Olson, M.P., "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," *Operations Research Letters*, 26, pp. 117-126.

THESES DIRECTED:

Oremis, S., "Funding Site Cleanup at Closing Army Installations: An Integer Linear Programming Approach," Masters Thesis, Naval Postgraduate School, December 2000.

Evans, J.A., "Who Responds and How Long Does it Take: Assigning Fire Station Areas of Responsibility," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Other (Optimization)

KEYWORDS: BRAC, Capital Budgeting, Optimization, Mixed Linear Integer Programming Application

PROJECT SUMMARIES

OPTIMALLY SCHEDULING EA-6B DEPOT MAINTENANCE

Robert F. Dell, Associate Professor
Department of Operations Research
Sponsor: Naval Air Systems Command

OBJECTIVE: The goal is to equip the EA-6B Program Office with a desktop, optimization-based decision-support tool to schedule all depot maintenance (standard depot-level maintenance, wing center-section replacements, and major aircraft modifications) for the EA-6B prowler fleet through 2015.

SUMMARY: We have formulated an optimization model to assist in scheduling EA-6B depot maintenance (standard depot-level maintenance, wing center-section replacements, and major aircraft modifications) and major aircraft modification-kit acquisition. The model produces an induction schedule providing monthly recommendations for the first six years, a yearly schedule out to 2013, and yearly major aircraft modification-kit acquisition levels out to 2010. We have performed extensive testing of alternate depot induction policies using the model to show their impact on yearly depot workloads and yearly operational aircraft.

PRESENTATION:

Baker, R.O., Dell, R.F., and Meeks, B.P., "Optimally Scheduling EA-6B Depot Maintenance," National Meeting of the Institute for Operations Research and the Management Sciences, Salt Lake City, UT, 7-10 May 2000.

THESIS DIRECTED:

Baker, R.O., "Optimally Scheduling EA-6B Depot Maintenance and Aircraft Modification Kit Procurement," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization, Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Scheduling

PLANNING CAPITAL INVESTMENTS USING OPTIMIZATION

Robert F. Dell, Associate Professor
Department of Operations Research
Sponsor: Office of Naval Research

OBJECTIVE: Conduct basic research in optimal planning of capital investments with two short-term subjects, (a) the Capital Investment Planning Aide (CIPA) for U. S. Navy Force Structure planning and (b) the Japan Petroleum Distribution model (JPDM) for US Navy infrastructure planning.

SUMMARY: This was the first year of a multi-year effort to conduct research on theory and algorithms for solving real-world capital-budgeting problems with prescriptive optimization. The first year had two short-term goals. The first was to enhance the Capital Investment Planning Aide (CIPA) for U. S. Navy Force Structure planning. We have formulated an optimization model of the Navy's spending plans for major weapons systems (e.g., ships and aircraft) and demonstrated it with current planning data. The second short-term goal was to enhance the Japan Petroleum Distribution model (JPDM) for U. S. Navy infrastructure planning. The Commander-in-Chief, United States Pacific Command (USCINCPAC) Joint Petroleum Office used JPDM in April 2000 during Exercise Joint Reception, Staging, Onward Movement and Integration (JRSOI 2000) and again in August 2000 for Exercise Ulchi Focus Lens.

PROJECT SUMMARIES

PUBLICATIONS:

Brown, G.G., Dell, R.F., and Olson, M.P., 2000, "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," *Operations Research Letters*, 26, pp. 117-126.

Newman, A.M., Brown, G.G., Dell, R.F., Giddings, A., and Rosenthal, R.E., 2000, "An Integer-Linear Program to Plan Procurement and Deployment of Space and Missile Assets," Naval Postgraduate School Technical Report, NPS-OR-00-005, April 2000.

PRESENTATIONS:

Brown, G.G., Dell, R.F., and Halwachs, T.E., "Implementing Optimization Based Models for Acquisition," SMART (Simulation & Modeling Acquisition Requirements Training) Conference 2000 sponsored by the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, Los Angeles, CA, 26-28 January 2000.

Dell, R.F., Brown, G.G., Field, R.J., and Newman, A.M., "Optimization Models for Military Capital Budgeting," 68th Military Operations Research Society Symposium, Colorado Springs, CO, 20-22 June 2000.

THESES DIRECTED:

Baran, N., "Optimizing Procurement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2000.

Noble, J.D., "Scheduling and Distributing Intra-Theatre Wartime POL Requirements," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization, Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting

OPTIMIZING NAVY PROGRAM PLANNING

Robert F. Dell, Associate Professor

Gerald G. Brown, Professor

Department of Operations Research

Sponsor: Chief of Naval Operations (N81)

OBJECTIVE: To provide N81 with a desktop, optimization-based decision support tool to integrate, rationalize, and schedule the way in which and the rate at which Navy capital spending programs should be conducted over the next 25 years.

SUMMARY: We have formulated an optimization model of the Navy's spending plans for major weapons systems (e.g., ships and aircraft) and demonstrated it with current planning data. Our goal is to prescribe complete scenarios that follow all Navy guidelines, including details such as keeping shipyards efficiently employed, synchronizing submarine production across yards, and meeting IWAR (Integrated Warfare Architecture) requirements. Program costs are nonlinear functions of volume, expressing the effects of learning and efficiencies of scale. The intent is to provide complete scenarios that can be used by the existing N81 scenario analysis tool EPA-TOA. Currently, complete scenarios must be manually assembled a slow, laborious task that frequently results in undetected errors. Our design has been briefed and approved, and we have started work on a graphical user interface.

PROJECT SUMMARIES

PRESENTATIONS:

Brown, G.G., Dell, R.F., and Halwachs, T.E., "Implementing Optimization Based Models for Acquisition," SMART (Simulation & Modeling Acquisition Requirements Training) Conference 2000 sponsored by the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, Los Angeles, CA, 26-28 January 2000.

Dell, R.F., Brown, G.G., Field, R.J., and Newman, A.M., 2000, "Optimization Models for Military Capital Budgeting," 68th Military Operations Research Society Symposium, Colorado Springs, CO, 20-22 June 2000.

THESES DIRECTED:

Baran, N., "Optimizing Procurement Planning of Navy Ships and Aircraft," Masters Thesis, Naval Postgraduate School, December 2000.

Field, R.J., "Planning Capital Investments in Navy Forces," Masters Thesis, Naval Postgraduate School, December 1999.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization, Decision Support)

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting, Decision Support

**PLANNING PROCUREMENT AND DEPLOYMENT
OF SPACE AND MISSILE ASSETS**
Robert F. Dell, Associate Professor
Gerald G. Brown, Professor
Richard E. Rosenthal, Professor
Department of Operations Research
Thomas E. Halwachs, Senior Lecturer
Sponsor: United States Air Force Space Command

OBJECTIVE: To model how the Air Force Space Command should procure space-based systems over a 25-year time horizon.

SUMMARY: The Space Command Optimizer of Utility Toolkit (SCOUT) is a linear integer program used by the Air Force Office of Aerospace Studies to help plan the research and development of space-based systems over a 25-year horizon. SCOUT recommends a mix of concepts, current systems, and launches that minimizes shortfalls in task performance while adhering to constraints on budget, launcher demand, launcher availability, and logical constraints governing the precedence and interdependence of systems. We have documented how SCOUT is used and analyzed alternate models to improve SCOUT's fidelity and performance.

PUBLICATIONS:

Newman, A.M., Brown, G.G., Dell, R.F., Giddings, A., and Rosenthal, R.E., "An Integer-Linear Program to Plan Procurement and Deployment of Space and Missile Assets," Naval Postgraduate School Technical Report, NPS-OR-00-005, April 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Space Vehicles

KEYWORDS: Optimization, Large-Scale Optimization, Program Planning, Budgeting, Capital Budgeting, Space Systems

PROJECT SUMMARIES

RESEARCH IN JOINT WARFARE MODELING AND SIMULATION, EMPHASIZING INFORMATION WARFARE ISSUES

D. P. Gaver, Distinguished Professor

P. A. Jacobs, Professor

Department of Operations Research

Sponsors: Director, Operational Test and Evaluation,

Institute for Joint Warfare Analysis of the Naval Postgraduate School,

DSO National Laboratories, Singapore,

Naval Air Systems Command and the Joint Staff (J8)

OBJECTIVE: Purpose of the research is to formulate and study state space models for information operations in joint warfare with a view towards guiding allocation of acquisition and eventually operational resources. The emphasis is on modeling the impact of information obtained from realistically imperfect sensor systems on interactive and joint conflicts

SUMMARY: State space models for time critical targeting represented in Fleet Battle Experiment Foxtrot have been developed, populated with data from that experiment and studied. Meta-models for ground combat that are populated with estimates obtained from a high-resolution combat model have been developed and studied.

PUBLICATIONS:

Becker, K.D., Gaver, D.P., Glazebrook, K.D., Jacobs, P.A., Lawphonpanich, S., "Allocation of Tasks to Specialized Processors: A Planning Approach," *European Journal of Operational Research*, Vol. 126, (2000) pp. 80-88.

Gaver, D.P., Jacobs, P.A., Youngren, M.A., and Parry, S.H., "JSTOCHWARS and Beyond: Models for Force Motion and Interaction that Represent Uncertain Perception," Naval Postgraduate Technical Report, NPS-OR-00-007, September 2000.

Gaver, D.P., Jacobs, P.A., and Pilnick, S.E., "Operations Analysis of Fleet Battle Experiments Using the Battlespace Information War Methodology," Naval Postgraduate School Technical Report, NPS-IJWA-01-008, October 2000.

Gaver, D.P. and Jacobs, P.A., "DISC-O-TIC: A Discrete-Time Analytical Meta-Model for Use in Combat Systems Studies that Utilize High-Resolution Simulation Models," Naval Postgraduate School Technical Report NPS-OR-01-005 and NPS-IJWA-01-009, December 2000.

THESIS DIRECTED:

Andrade, S., "An Intelligent Agent Simulation of Shipboard Damage Control," Master's Thesis, Naval Postgraduate School, June 2000.

OTHER:

Bullock, G., "Delphi Software Implementation of Models for Blue Force Response to Region Invasion by Multi-Type Red Forces," September 2000.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Modeling and Simulation

KEYWORDS: Combat Models, Bayesian Perception Updating, Decision Analysis

PROJECT SUMMARIES

TRAINING AND RESEARCH SUPPORT FOR DIRECTOR, OPERATIONAL TEST AND EVALUATION

D. P. Gaver, Distinguished Professor

P. A. Jacobs, Professor

Department of Operations Research

Sponsors: Director, Operational Test and Evaluation and

U. S. Army TRADOC Analysis Command

OBJECTIVE: Purpose of the research is to develop training and reference material on a web site and new methodology for operational testing use emphasizing modeling and simulation.

SUMMARY: Models for sequential stage system reliability growth via failure mode removal have been formulated and studied. Models to assess the operational suitability of sensor platforms have been formulated and studied. Materials for an operational test and evaluation web site have been developed.

PUBLICATIONS:

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "System Reliability Growth via Failure Mode Removal," *Livre des Actes*, Vol. 1, MMR 2000, Methodology, Practice and Inference, 2nd International Conference on Mathematical Methods in Reliability. Laboratoire Statistique Mathématique et ses Applications, Université Victor Ségalen, Bordeaux, France, pp. 439-442.

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "Reliability Growth in Stage-Wise-Functioning Systems by Failure Mode Removal," *Agenda Book for Workshop on Reliability Issues for DoD Systems*, 9-10 June 2000.

Gaver, D.P., Glazebrook, K.D., Jacobs, P.A., and Seglie, E.A., "Probability Models for Sequential-Stage System Reliability Growth Via Failure Mode Removal," Naval Postgraduate School Technical Report, NPS-OR-00-006, September 2000.

PRESENTATIONS:

Gaver, D.P., Jacobs, P.A., Olwell, D., and E. Seglie, E.A., "Probability Models for Sequential Stage System Reliability Growth Via Failure Mode Removal," Workshop on Reliability Issue for DoD Systems, Washington D.C., 9-10 June 2000.

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "Decision Criteria that Support Learning from Operational Testing," Joint Research Conference on Statistics in Quality, Industry and Technology, Seattle, WA, 26-28 June 2000.

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "System Reliability Growth Via Failure Mode Removal," Second International Conference on Mathematical Methods in Reliability, Bordeaux, France, 4-7 July 2000.

THESIS DIRECTED:

Unrath, C. "Dynamic Exploration of Helicopter Reconnaissance Through Agent-Based Modeling," Masters Thesis, Naval Postgraduate School, September 2000.

OTHER: Spreadsheet implementation of simulation of reliability tests

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Modeling and Simulation

KEYWORDS: Military Test and Evaluation, Statistical Data Analysis, Decision Analysis, Modeling and Simulation

PROJECT SUMMARIES

EXPLORATORY AEA MODELING AND ANALYSIS, USING BAT/IW

D. P. Gaver, Distinguished Professor

P. A. Jacobs, Professor

Department of Operations Research

Sponsor: Naval Air Systems Command

OBJECTIVE: Conduct exploratory scooping and analysis of options for follow-on to the EA6B AEA/SEAD Aircraft using modified BAT/IW. Consult on later phases of the AOA.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Modeling, Simulation, Operations Analysis, Electronic Warfare

TOXICITY OF INHALED JET FUELS: RATIONAL ORGAN AND NEUROBEHAVIORAL TOXICITY ASSESSMENT OF A COMPLEX MIXTURE

D. P. Gaver, Distinguished Professor

P. A. Jacobs, Professor

Department of Operations Research

Sponsor: Naval Health Research Center Detachment – Toxicology

OBJECTIVE: Use mathematical computer-based modeling and statistical methods to quantify the neuropsychological effects of complex jet fuel multi-component vapors on operating personnel.

SUMMARY: Mechanistic models for the effect of a toxic substance on the liver have been developed.

DoD KEY TECHNOLOGY AREAS: Biomedical, Human Systems Interface, Environmental Quality

KEYWORDS: PBPK/PD Compartment Modeling, Predictive Toxicology, Mixture Toxicology

DEVELOPMENT OF A RESEARCH AND DEVELOPMENT PROGRAM AND METHODOLOGY FOR THE GOVERNMENT OF POLAND

Thomas H. Hoivik, Senior Lecturer

Department of Operations Research

Sponsor: Poland Extended International Military Education and Training (EIMET)

OBJECTIVE: To develop and establish a new military research, development and testing capability within the Polish government and industry that would allow Poland to significantly contribute to the NATO warfighting capability.

SUMMARY: This research project was in response to the Polish Ministry of Defense's request to DOD for help in establishing a new military research and development capability compatible with NATO nation models and organization structures. It entailed development of an initial long-range plan for establishing an effective RDT&E organization with a Life-Cycle Management Capability tailored to meet Polish Ministry of Defense (MOD) requirements and constraints. The focus of this research was to integrate the basic principles of systems engineering, decision analysis, and acquisition methodology into the Ministry of Defense's organization without threatening individual job security and power positions. It involved converting Polish MOD scientific and engineering personnel from the old Communist way of thinking into a systems engineering and analysis philosophy that included as a minimum, initial mission need and requirement analysis, tradeoff methodologies, the developmental process, cost-performance analysis, technical performance measurement, testing, production alternatives, and life-cycle logistics support.

A five-day RDT&E course was developed and presented to senior MOD executives and officials in Warsaw. The course included principles of systems engineering for high-technology programs, requirements analysis, system cost estimation, decision analysis, and acquisition process methodologies. It was well received by all attendees including Dr. Santorof, the head of the Polish Research and

PROJECT SUMMARIES

Development Organization. As a result, Poland has requested continuing assistance from NPS in restructuring their MOD RDT&E process.

PUBLICATIONS:

Hoivik, T.H., "System Engineering for Polish High Technology Research and Development Programs," Poland MOD Distribution, December 1999.

DoD KEY TECHNOLOGY AREAS: Other (Systems Engineering)

KEYWORDS: Research and Development, Test and Evaluation, Systems Engineering

RESEARCH IN APPLIED STATISTICS: CAPTURE-RECAPTURE METHODS AND MEASUREMENT ERROR MODELS

**Robert A. Koyak, Assistant Professor
Department of Operations Research**

Sponsor: Naval Postgraduate School Research Initiation Program

OBJECTIVE: Initiate research into applied statistical problems related to two areas of methodology: (i) estimation of the size of a population using capture-recapture methods, and (ii) model fitting and estimation when predictor variables are measured with error.

SUMMARY: Research in CY 2000 was funded for one quarter. During that time I continued to work on problems related to raking, a technique which is used to smooth capture-recapture estimates of population size. Funding from the William F. Donner Foundation was received in FY 2000 for research that was done in FY 1999 on capture-recapture models in the U.S. decennial census. This research was described in a paper that was published in conference proceedings in CY 1999. A paper that extends this work is in progress and will be submitted to an academic journal in CY 2001.

PUBLICATIONS:

Koyak, R.A., Schmehl, R.L., Cox, D.C., Dewalt, F.G., Haugen, M.M., Schwemberger, John G. Jr., and Scalera, John V., 2000, "Statistical Models for the Evaluation of Portable Lead Measurement Technologies--Part II: X-Ray Fluorescence Instruments," *Journal of Agricultural, Biological, and Environmental Statistics*, 5, pp. 37-57.

DoD KEY TECHNOLOGY AREAS: Other (Probability and Statistics)

KEYWORDS: Statistics, Capture-Recapture

DUAL SYSTEM ESTIMATION IN CENSUS 2000: HOW DOES RAKING DIFFER FROM SMOOTHING?

**Robert A. Koyak, Assistant Professor
Department of Operations Research
Sponsor: William F. Donner Foundation**

OBJECTIVE: Investigate the characteristics of "raking" in contrast to traditional smoothing techniques in connection with statistical adjustment of the U.S. decennial census.

SUMMARY: Funding from the William F. Donner Foundation was received in FY 2000 for research that was done in FY 1999 on capture-recapture models in the U.S. decennial census. This research was described in a paper that was published in conference proceedings in CY 1999. A paper that extends this work is in progress and will be submitted to an academic journal in CY 2001.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Other (Probability and Statistics)

KEYWORDS: Statistics, Raking, Census

STATISTICAL RESEARCH IN JOINT INTEROPERABILITY TESTING OF THEATER MISSILE DEFENSE SYSTEMS

Robert A. Koyak, Assistant Professor

Department of Operations Research

Sponsors: Defense Information Systems Agency, Joint Interoperability Test Command

OBJECTIVE: The focus of this research was to explore means by which the Joint Interoperability Test Command (JITC) could extend its interoperability-testing program for Theater Missile Defense families of systems to emphasize performance, in contrast to standards compliance.

SUMMARY: The Department of Defense requires that all command, control, communications and computer intelligence (C4I) systems and automated information systems (AIS) be certified as interoperable between the services. JITC is responsible for the testing and certification of these systems. Its testing mission encompasses Theater Missile Defense families of systems, in which assets across services are used to jointly track and engage ballistic missile threats. The development of performance-based metrics for assessing interoperability requires a detailed understanding not only of interoperability concepts, but also of the physics of ballistic missile trajectories, and of uncertainties inherent in multi-sensor, multi-target data fusion.

PUBLICATION:

Koyak, R.A., "Joint Interoperability of Theater Missile Defense Systems: Extending the Scope of Testing," Naval Postgraduate School Technical Report, NPS-OR-01-001, October 2000.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Sensors, Other (Theater Air and Missile Defense, Interoperability, Test and Evaluation)

KEYWORDS: C4I, Automated Information Systems, Ballistic Missile Threats

DECOMPOSITION WITH TRUNCATED SUBPROBLEMS

Siriphong Lawphongpanich, Associate Professor

Department of Operations Research

Sponsor: Unfunded

OBJECTIVE: To investigate properties and efficiency of decomposition techniques for mathematical programs in which the sub problems are solved crudely.

SUMMARY: In 2000, the investigation focused on decomposition strategies that result in nonlinear optimization sub problems. In practice, such strategies are typically ignored because the sub problems are computationally expensive to solve. However, this investigation was able to show that, instead of solving the nonlinear sub problems to optimality or nearly so, it is possible to truncate their solution algorithms after completing only one or two iterations and still guarantee theoretical convergence under some non-restrictive assumptions. An experiment with small nonlinear multicommodity network flow problems indicates that the technique is efficient and merits further investigation.

PUBLICATIONS:

Lawphongpanich, S., 2000, "Simplicial with Truncated Dantzig-Wolfe Decomposition for Nonlinear Multicommodity Network Flow Problems with Side Constraints," *Operations Research Letters*, 26, pp. 33-41.

PROJECT SUMMARIES

DoD KEY TECHNOLOGY AREAS: Other (Optimization Techniques)

KEYWORDS: Decomposition, Optimization, Network Flows

ECONOMETRIC PROJECTION OF ARMY PERSONNEL STRENGTH

Siriphong Lawphongpanich, Associate Professor

Department of Operations Research

Sponsor: U. S. Army Office of Deputy Chief of Staff (Personnel)

OBJECTIVE: This study will develop an econometric model for forecasting retention rates of Army officers and enlisted personnel. The model will include economic, demographic, and service-specific factors relevant to the decision to remain in the Army. The main goal of this study is to replace the exponential technique used in the current Army's strength management system with the econometric model.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Army's Strength Management System, Econometric Forecasting Model, Retention Rate

TREE-BASED METHODS FOR FORECASTING RETENTION RATES

Siriphong Lawphongpanich, Associate Professor

Department of Operations Research

Sponsor: U. S. Army Office of Deputy Chief of Staff (Personnel)

OBJECTIVE: One-third of the Army's budget is allocated to the Military Personnel Account (MPS); the key element of the MPA budget is determined by required strength projections for future forces. Forecasts of military strength are heavily dependent on prediction of retention rates for current personnel. This research will investigate the use of tree-based clustering methods and alternative forecasting procedures in improving the forecasts of retention rates for current personnel.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Clustering, Tree-Based Methods, Retention Forecasts

LONGITUDINAL STUDY OF TRAINING DEADTIME

R. R. Read, Professor

Department of Operations Research

Sponsor: Chief of Naval Operations (N813)

OBJECTIVE: Recent studies have provided quantitative information relating to the very high cost of dead time (time that sailors are not undergoing training although assigned for training) in the Navy training system. These studies are based upon quarterly and monthly average on board (AOB) data, which provided the period, averages for numerous categories of dead time and non-dead time. Data of this type are readily accessible. It has been suggested that a different data structure, i.e., longitudinal data which records the time spent by sailors in the various categories measured from the beginning of the courses, may provide sharper information about what is happening in some instances and help to better understand the nature of the problems, their relative importance, and suggest types of remedial action.

SUMMARY: The present report presents some models of the longitudinal type and fits them to data. Specifically it treats the holding-time distributions measured from the beginning of a course until the entrance into a non-training state for academic attritions, academic setbacks, and interrupted instruction of the non-legal-holiday type. Analysis shows that there is considerable variability of these distributions from course to course and year to year. Also, the within-course variability is substantial. The process is

PROJECT SUMMARIES

modeled as a non-homogeneous Poisson process. But there appears to be no stock models for the mean value function that are of general use. So these functions are modeled as step functions and the break points are estimated by maximum likelihood. It appears that at least five break points are needed for the courses studied. Also considered are the data needs for the longitudinal study of the downtimes between courses in a pipeline of courses.

PUBLICATIONS:

Read, R., Washburn A., and Thomas, L., 2000, "Estimating Means When Sampling Gives Probabilities as Well as Values or 'Looking a Gift Horse in the Mouth'," *Statistics and Computing* 10, pp. 245-252.

Read, R. R. "Longitudinal Studies Relating to Training Dead Time," to appear as an Naval Postgraduate School Technical Report in 2001.

PRESENTATION:

Read, R., 2000, "Rating and Prediction Using an Enhanced Bradley - Terry Model," Joint National Meetings of ASA, IMS, IBS, August, IN.

THESIS DIRECTED:

Li, Joseph, "A Poisson Regression Analysis of the Academic Setback in Naval Training Dead Time," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation

KEYWORDS: Statistics, Military Training

METHODOLOGY RESEARCH IN WARGAMING AND ANALYSIS

Richard E. Rosenthal, Professor
Donald Gaver, Distinguished Professor
Patricia Jacobs, Professor
Department of Operations Research
Sponsor: Joint Staff (J8)

OBJECTIVE: This is a continuation of research in Operations Methodology to support Joint Combat Analysis in the Force Structure, Resources and Assessment Directorate, Warfighting Analysis Division.

DoD KEY TECHNOLOGY AREAS: Computing and Software

KEYWORDS: Military Operations Research and Analysis

LAND ATTACK PREDESIGNATION (LAP)

Richard E. Rosenthal, Professor
Alexandra M. Newman, Research Assistant Professor
Department of Operations Research
Sponsor: Naval Surface Warfare Center-Dahlgren Division

OBJECTIVE: To optimally predesignate Tomahawk land attack missile strikes among units of a battle group.

SUMMARY: The Tomahawk land attack missile (TLAM) is the Navy's weapon of choice for striking shore targets from the sea. A TLAM launched from a surface combatant or a submarine is a reliable,

PROJECT SUMMARIES

unmanned, long-range, accurate weapon with sufficient payload to threaten almost any shore target. We have developed optimization-based decision support tools to optimize TLAM strikes from single firing units or entire battle groups. The idea is to execute each strike efficiently while retaining residual firepower, and while considering a number of other essential details. By applying mathematical modeling, the result is the ability to plan fleet and theater-wide strikes in seconds.

PUBLICATION:

Brown, G.G., Newman, A.M., Rosenthal, R.E., and Rowe, A, "Optimizing Tomahawk Strikes," Naval Postgraduate School Project Report, NPS-OR-01-001-PR, April 2000.

THESES DIRECTED:

Arnold, A., "A Fast Heuristic for Land Attack Predestination," Masters Thesis, Naval Postgraduate School, June 2000.

Hodge, B.C., "A Heuristic for Land Attack Predestination," Masters Thesis, Naval Postgraduate School, December 1999.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Optimization, Weapon Allocation

GENERALIZED NETWORK ENLISTED COMPONENT OF THE ACTIVE ARMY STRENGTH FORECASTER

Richard E. Rosenthal, Professor

Laura M. Williams, Research Assistant Professor

Department of Operations Research

Sponsor: U. S. Army Office of the Deputy Chief of Staff (Personnel)

OBJECTIVE: To research and design a prototype model to post-process the results of the generalized-network enlisted-with-grade model (EG) of the Active Army Strength Forecaster (A2SF). The purpose of the model is to distribute the losses and promotions forecasted by the EG model into the Military Occupational Specialty (MOS) dimension.

SUMMARY: A prototypic Enlisted Specialty (ES) model formulation has been developed and delivered to the sponsor. The proposed ES model will optimally distribute the accessions, losses, promotions and Program Managed Losses (PMLs) forecasted by the EG model over the MOS dimension, as well as track the training and operating strength inventories by gender, grade and specialty. Additional features of the model include the handling of reclassifications between specialties, promotion zones and quality issues particular to each specialty.

PRESENTATIONS:

Williams, L.M. and Galing, S.E., "Redesigning the U.S. Army's Enlisted Manpower Forecasting Models," MORS Symposium, Air Force Academy, June 2000.

Williams, L.M. and Sweetser, W.A., "Redesigning the U.S. Army's Enlisted Manpower Forecasting Models," Navy Manpower Research and Analysis Conference, Center for Naval Analysis, October 2000.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel and Training

KEYWORDS: Manpower, Optimization

PROJECT SUMMARIES

OPTIMIZATION MODELING IN SUPPORT OF TANKER REQUIREMENTS STUDY FOR 2005

Richard E. Rosenthal, Professor
Laura M. Williams, Research Assistant Professor
Anton Rowe, Research Assistant
Department of Operations Research
Lt Col Steven F. Baker, USAF
Naval War College

Sponsor: Office of the Secretary of Defense (PA&E)

OBJECTIVE: Air Mobility Command, Studies and Analysis Flight, is currently conducting a tanker requirements study (TRS-05). This new study is driven by the upcoming need to replace the KC-135 aircraft. An analysis of the tanker requirement will be an important input to the Analysis of Alternatives (AoA).

This study, the Optimization Modeling in Support of the TRS-05, supplements and enhances the TRS-05. The Naval Postgraduate School/Rand Mobility Optimizer (NRMO) was used to provide analysis of the tanker requirement in support of air mobility operations. The use of an optimization model offers unique insights that could guide investment decisions and allow more accurate judgment of tradeoffs between infrastructure investments and aircraft procurement investments. The primary objective was to determine the number of tanker airframes and aircrews needed to support the air mobility functions in the years 2005 and beyond.

SUMMARY: OSD and the Joint Staff have developed a series of all-services halt-phase Time-Phased Force Deployment Documents (TPFDDs) for use in the current Mobility Requirements Study (MRS-05), which are also the basis for the TRS-05 study. In this, the first year of the TRS-05, the non-WMD West-East MTW scenario has been converted for use by the NRMO model and validated against the results obtained by AMC/XPY using their legacy simulation model. A thorough analysis of tanker usage was performed using this scenario as well as excursions which parametrically alter the tanker force, airlift force, wind velocity, resource usage assumptions and base closures and limitations. Results of the analysis were briefed both at a MORS conference and to the sponsor, OSD (PA&E).

PUBLICATIONS:

Baker, S.F., Morton, D., Rosenthal, R.E., and Williams, L.M., "Optimizing Military Airlift," in review.

PRESENTATION:

Williams, L.M., Baker, S.F., and Rosenthal, R.E., "NRMO Enhancements and Modifications for TRS-05," MORS Symposium, Air Force Academy, June 2000.

DoD KEY TECHNOLOGY AREAS: Other (Optimization, Airlift, Mobility, Military Logistics)

KEYWORDS: Mobility, Air Mobility, Optimization, Tankers

SEA BASED LOGISTICS

D.A. Schrady, Distinguished Professor
Department of Operations Research

Sponsor: Naval Postgraduate School Institute for Joint Warfare Analysis

OBJECTIVES: To identify the operational factors that are critical to the viability of sea-basing the logistical support of forces operating ashore.

SUMMARY: Substantial work on sea based logistics modeling was accomplished and a technical report was completed. Analysis focused on the operational aspects of the concept of sea based logistics (SBL) including characterization of the range of types and sizes of forces to be supported by SBL, estimation of

PROJECT SUMMARIES

the sustainment requirements of such forces, and determination of the feasibility of SBL sustainment for the forces postulated. Having identified the critical factors affecting the feasibility of sea-based logistics, the 1982 Falklands War was examined in detail as the modern example of a plan to sea-based logistics.

PUBLICATION:

Schrady, D.A., "Sea-Based Logistics and Lessons from the Falklands," Naval Postgraduate School Technical Report, NPS-IJWA-00-002, May 2000.

PRESENTATION:

Schrady, D.A., "Sea-Based Logistics and Lessons from the Falklands," International Symposium on Military Operational Research, Shrivenham, United Kingdom, 31 August 2000.

THESIS DIRECTED:

Frey, Christopher M., "An Evaluation of Sea-Based Sustainment of Forces," Masters Thesis, Naval Postgraduate School, September 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Naval Logistics, Sustainability, Sea-Based Logistics, OMFTS

ECONOMIC BENEFIT OF NAVAL FORWARD PRESENCE

D.A. Schrady, Professor

Department of Operations Research

R.L. Looney, Professor

Department of National Security Affairs

Sponsor: Chief of Naval Operations (N81)

OBJECTIVE: To evaluate the linkage between naval forward presence and economic security, peacetime interests, and globalization.

SUMMARY: In anticipation of the congressionally mandated 2001 Quadrennial Defense Review, our earlier research (1997) on the economic benefits of naval forward presence and crisis response was expanded in several significant ways. Four new crises, beyond the three used in the earlier research, were examined. Not only were these cases different, but they also differed in respect to the direct threat to world oil availability. Thus benefits were evaluated not just in terms of oil futures prices but also in terms of currency exchange ratios and U. S. and international equity markets. Finally, the question of causality between naval crisis response and improvement in energy prices, exchange ratios and equity market indices was examined using an adaptation of regression techniques called Event Analysis. The findings of the first study are confirmed with naval forward presence/crisis response shown to produce extensive economic benefits for the U. S. economy in each of the cases examined.

PUBLICATION:

Looney, R. and Schrady, D., "Estimating Economic Benefits of Naval Forward Presence," Naval Postgraduate School Technical Report, NPS-OR-01-004, October 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Naval Forward Presence, Economic Benefits, Econometrics

PROJECT SUMMARIES

SUPPORT AND REVIEW OF THE MODELING OF GROUND COMBAT IN INTEGRATED THEATER ENGAGEMENT MODEL

James G. Taylor, Professor

Department of Operations Research and
Modeling, Virtual Environments, and Simulation Academic Group

Sponsor: Joint Training, Analysis, and Simulation Center

OBJECTIVE: To provide necessary background and inputs for specific topics and methodologies, concerning the representation of ground combat, of interest to the Joint Training, Simulation and Analysis Center (JTASC) to support its use/development of the Integrated Theater Engagement Model (ITEM)

SUMMARY: This work was originally funded to investigate the theoretical basis of the attrition calibration (ATCAL) approach, with an eye on improving how ground-combat attrition and opposed-force movement are played in the Integrated Theater Engagement Model (ITEM). With the advent of JWARS, however, the sponsor directed that efforts be redirected towards helping improve ground-combat attrition in JWARS. Consequently, research focused on the development of new results for single-weapon-system-type kill rates in Lanchester-type combat models, which OSD PA&E will consider for the direct-fire ground-combat attrition algorithm in JWARS. Only a small amount of time remained for this project during the reporting period.

PUBLICATION:

Taylor, J. G., Yildirim, U. Z., and Murphy, W. S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," *Proceedings of the 2000 Winter Simulation Conference*, J.A. Joines, R.R. Barton, K. Kang, and P.A. Fishwick (eds.), Winter Simulation Conference, Orlando, FL, December 2000, pp. 925-932.

PRESENTATION:

Taylor, J. G., Yildirim, U. Z., and Murphy, W. S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," 2000 Winter Simulation Conference, Orlando, FL, 11 December 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Ground-Force-on-Force Attrition, Attrition-Calibration (ATCAL) Method, Joint-Warfare Campaign Models

JOINT COMBAT CAPABILITY

Alan Washburn, Professor

Gerald Brown, Professor

Department of Operations Research

Sponsor: Joint Staff (J8) and Naval Postgraduate School

OBJECTIVE: A prototypic combat model called JCCM (Joint Combat Capability Model) was developed and delivered to J8 in 1999. JCCM incorporates multiple phases of a war, terminating each at a time dependent on the state of the battle. The modeled war consists of 3-day periods, in each of which is fought an optimized air-to-ground battle and a non-optimized ground-to-ground battle. The two parts communicate through surviving numbers of platforms, munitions, and targets. The JCCM air-to-ground model is realistic, but the ground-to-ground model is not. The objective in FY2000 is to incorporate a realistic ground-to-ground model.

SUMMARY: The Army's COSAGE model of ground combat identifies both direct and indirect fire in its killer-victim scoreboards. A Lanchester equivalent, complete with a mechanism for reprogramming direct fire, has been built into JCCM. A master FORTRAN program reads the COSAGE scoreboards, calculates the Lanchester coefficients, and then alternately runs the ground-to-ground model or calls a linear program solver for the air-to-ground part. Some targets are vulnerable to ground platforms, some to air platforms,

PROJECT SUMMARIES

and some to both. The model has been renamed Fast Theater Model (FATHM). FATHM requires about 20 minutes to fight a five-phase war to completion. Software has been delivered to J8.

PUBLICATION:

Washburn, A. and Brown, G., "The Fast Theater Model (FATHM)," Naval Postgraduate School Technical Report, NPS-OR-01-002-PR, 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: Optimization, Weapon Allocation

NAVY AIRLIFT

Alan Washburn, Professor
Department of Operations Research
William Gates, Associate Professor
Department of Systems Management
Sponsor: Chief of Naval Operations (N87)

OBJECTIVE: The Navy operates a fleet of operational support aircraft (OSA) that have the function of moving high priority passengers and cargo in wartime. The fleet is aging, and must gradually be replaced with more modern aircraft. The objective is first to measure the wartime demand for OSA transport in the event of a major war, and then to design a fleet that satisfies that demand at minimal cost.

SUMMARY: This study will be completed in FY2001.

THESIS DIRECTED:

Law, J., "Assessing the Performance and Cost of Logistics Airfleet Options," Masters Thesis, Naval Postgraduate School, December 2000.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation

KEYWORDS: OSA, Aircraft Scheduling

LARGE-SCALE MIXED INTEGER PROGRAMMING

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: Joint Warfare Analysis Center

OBJECTIVE: This continuing research program seeks to develop theory and algorithms for solving analytical models related to civilian and military infrastructure.

SUMMARY: Available from sponsor.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization, Infrastructure

PROJECT SUMMARIES

SUMMER PROGRAM IN OPERATIONS RESEARCH TECHNOLOGY

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: National Security Agency

OBJECTIVE: Provide leadership and technical guidance to graduate students in NSA's Summer Program for Operations Research Technology

SUMMARY: Professor Wood spent three months with NSA's Operations Research Group in Columbia, Maryland guiding graduate students in their analysis of some emergent OR problems at NSA. These problems included a simulation model of part of NSA's semiconductor production facility, some manpower issues, network interdiction and a number of classified topics. Classified project summaries were provided to NSA management upon completion of all projects.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

SUPPORT FOR THE CENTER FOR OPERATIONS RESEARCH, NATIONAL SECURITY AGENCY

R. Kevin Wood, Professor
Department of Operations Research
Sponsor: National Security Agency

OBJECTIVE: Provide on-call analytical support to the National Security Agency.

THESIS DIRECTED:

Gibbons, M. J., "Enumerating Near-Minimum Cuts in a Network," Masters Thesis, Naval Postgraduate School, June 2000.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Modeling and Simulation, Other (Optimization and Decision Support)

KEYWORDS: Optimization

**DEPARTMENT OF
OPERATIONS RESEARCH**

**2000
Faculty Publications
and Presentations**

PUBLICATIONS/PRESENTATIONS

JOURNAL PAPERS

Becker, K.D., Gaver, D.P., Glazebrook, K.D., Jacobs, P.A., Lawphonpanich, S., "Allocation of Tasks to Specialized Processors: A Planning Approach," *European Journal of Operational Research*, Vol. 126, (2000) pp. 80-88.

Brown, G., Dell, R., and Olson, M., 2000, "Valid Integer Polytope (VIP) Penalties for Branch-and-Bound Enumeration," *Operations Research Letters*, 26, pp. 117-126.

Koyak, R.A., Schmehl, R.L., Cox, D.C., Dewalt, F. Gary, Haugen, M.M., Schwemberger, J.G. Jr., and Scalera, J.V., 2000, "Statistical Models for the Evaluation of Portable Lead Measurement Technologies--Part II: X-Ray Fluorescence Instruments," *Journal of Agricultural, Biological, and Environmental Statistics*, 5, pp. 37-57.

Lawphongpanich, S., 2000, "Simplicial with Truncated Dantzig-Wolfe Decomposition for Nonlinear Multicommodity Network Flow Problems with Side Constraints," *Operations Research Letters*, 26, pp. 33-41.

Read, R., Washburn A., and Thomas, L., 2000, "Estimating Means When Sampling Gives Probabilities as Well as Values or 'Looking a Gift Horse in the Mouth'," *Statistics and Computing* 10, pp. 245-252.

CONFERENCE PAPERS

Gaver, D.P., Jacobs, P.A., and Seglie, E.A., "System Reliability Growth via Failure Mode Removal," *Livre des Actes*, Vol. 1, MMR 2000, Methodology, Practice and Inference, 2nd International Conference on Mathematical Methods in Reliability. Laboratoire Statistique Mathématique et ses Applications, Université Victor Ségalen, Bordeaux, France, pp. 439-442.

Taylor, J.G., Yildirim, U.Z., and Murphy, W.S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," *Proceedings of the 2000 Winter Simulation Conference*, J.A. Joines, R.R. Barton, K. Kang, and P.A. Fishwick, eds., Winter Simulation Conference, Orlando, FL, December 2000, pp. 925-932.

CONFERENCE PRESENTATIONS

Akgun, I. and Wood, R.K., "Multi-Unit Network Interdiction," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Applegate, J. and Wood, R.K., "Explicit-Constraint Branching for Solving Mixed-Integer Programs," 7th INFORMS Computing Society Conference, Cancun, Mexico, 5-7 January 2000.

Baker, R.O., Dell, R.F., and Meeks, B.P., "Optimally Scheduling EA-6B Depot Maintenance," National Meeting of the Institute for Operations Research and the Management Sciences, Salt Lake City, UT, 7-10 May 2000.

Bradley, G. and Buss, A., "Architecture for Dynamic Planning Systems Using Loosely Coupled Components," IFIP WORKING GROUP 7.6 Workshop on Virtual Environments for Advanced Modeling, Monterey, CA, 2-4 August 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," Inter-service Mission Planning Working Group Meeting (IMPWG), Huntsville, AL, 24-25 October 2000.

Bradley, G., Buss, A., Parker, J., and Sanchez, P., "Loosely Coupled Components Laboratory - Overview and Open House," Department of Operations Research Seminar, Monterey, CA, 27 January 2000.

PUBLICATIONS/PRESENTATIONS

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," OASD SO/LIC Special Operations C4I R&D Workshop, McLean, VA, 19-21 July 2000.

Bradley, G. and Buss, A., "Architecture for Dynamic Planning Systems Using Loosely Coupled Components," IFIP WORKING GROUP 7.6 Workshop on Virtual Environments for Advanced Modeling, Monterey, CA, August 2000.

Bradley, G. and Parker, J., "Loosely Coupled Components Working Group," Inter-service Mission Planning Working Group Meeting (IMPWG), Huntsville AL, 24-25 October 2000.

Bradley, G. and Buss, A., "Loosely Coupled Components Project: Map-Based Military Planning," The Third International Meeting of the INFORMS Military Application Society, San Antonio, TX, 5-8 November 2000.

Brown, G.G., Dell, R.F., and Halwachs, T.E., 2000, "Implementing Optimization Based Models for Acquisition," SMART (Simulation & Modeling Acquisition Requirements Training) Conference 2000 sponsored by the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, Los Angeles, CA, 26-28 January 2000.

Dell, R.F., Brown, G.G., Field, R.J., and Newman, A.M., "Optimization Models for Military Capital Budgeting," 68th Military Operations Research Society Symposium, Colorado Springs, CO, 20-22 June 2000.

Gaver, D. P., Jacobs, P. A., Olwell, D., and E. Seglie, E. A., "Probability Models for Sequential Stage System Reliability Growth Via Failure Mode Removal," Workshop on Reliability Issue for DoD Systems, Washington D.C., 9-10 June 2000.

Gaver, D. P., Jacobs, P. A., and Seglie, E. A., "Decision Criteria that Support Learning from Operational Testing," Joint Research Conference on Statistics in Quality, Industry and Technology, Seattle, WA, 26-28 June 2000.

Gaver, D. P., Jacobs, P. A., and Seglie, E. A., "System Reliability Growth Via Failure Mode Removal," Second International Conference on Mathematical Methods in Reliability, Bordeaux, France, 4-7 July 2000.

Morton, D., Salmeron, J., and Wood, R.K., "New Decomposition-Based Techniques for Solving Two-Stage Stochastic Programs," International Symposium on Mathematical Programming, Atlanta, GA, 7-11 August 2000.

Read, R., 2000, "Rating and Prediction Using an Enhanced Bradley - Terry Model," Joint National Meetings of ASA, IMS, IBS, August, IN.

Salmeron, J. and Wood, K., "Solving Stochastic Network Interdiction Problems," INFORMS National Meeting, San Antonio, TX, 5-8 November 2000.

Salmeron, J. and Wood, R.K., "A Sampling-Based Cutting Plane Method for Stochastic Programs," INFORMS National Meeting, Salt Lake City, UT, 7-10 May 2000.

Schrad, D.A., "Sea-Based Logistics and Lessons from the Falklands," International Symposium on Military Operational Research, Shrivenham, United Kingdom, 31 August 2000.

Taylor, J. G., Yildirim, U. Z., and Murphy, W. S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," 2000 Winter Simulation Conference, Orlando, FL, 11 December 2000.

Williams, L.M., Baker, S.F. and Rosenthal, R.E., "NRMO Enhancements and Modifications for TRS-05," MORS Symposium, Air Force Academy, June 2000.

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Williams, L.M. and Galing, S.E., "Redesigning the U.S. Army's Enlisted Manpower Forecasting Models," MORS Symposium, Air Force Academy, June 2000.

Williams, L.M. and Sweetser, W.A., "Redesigning the U.S. Army's Enlisted Manpower Forecasting Models," Navy Manpower Research and Analysis Conference, Center for Naval Analysis, October 2000.

Wood, R.K. "Network Interdiction and Eavesdropping," Colloquium in Engineering Economic Systems and Operations Research, Stanford University, Palo Alto, CA, 9 May 2000.

Wood, R.K., "Network Interdiction and Eavesdropping," National Security Agency, Operations Research and Management Science Symposium, 11 April 2000.

CONTRIBUTION TO BOOKS

Applegate, J. and Wood, K., 2000, "Explicit-Constraint Branching for Solving Mixed-Integer Programs," *Computing Tools for Modeling, Optimization and Simulation*, M. Laguna and J.L. González-Velarde, eds., Kluwer Academic Publishers, Boston, pp. 243-261.

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Brown, G.G. and Washburn, A., Dell, R.F., Giddings, A., and Rosenthal, R., "An Integer-Linear Program to Plan Procurement" and "The Fast Theater Model (FATHM)," Naval Postgraduate School Project Report, NPS-OR-01-002-PR, October 2000.

Buss, A.H. and Halwachs, T., "Core Validation for Maritime Operations Simulation (MarOpsSim)," Naval Postgraduate School Technical Report NPS-OR-00-003, 2000.

Gaver, D. P., Jacobs, P. A., Youngren, M. A., and Parry, S. H., "Jstochwars and Beyond: Models for Force Motion and Interaction that Represent Uncertain Perception," Naval Postgraduate Technical Report, NPS-OR-00-007, September 2000.

Gaver, D. P., Jacobs, P. A., and Pilnick, S. E., "Operations Analysis of Fleet Battle Experiments Using the battlespace Information War Methodology," Naval Postgraduate School Technical Report, NPS-IJWA-01-008, October 2000.

Gaver, D. P. and Jacobs, P. A., "DISC-O-TIC: A Discrete-Time Analytical Meta-Model for Use in Combat Systems Studies that Utilize High-Resolution Simulation Models," Naval Postgraduate School Technical Reports NPS-OR-01-005 and NPS-IJWA-01-009, December 2000.

Gaver, D. P., Glazebrook, K. D., Jacobs, P. A., and Seglie, E. A., "Probability Models for Sequential-Stage System Reliability Growth Via Failure Mode Removal," Naval Postgraduate School Technical Report, NPS-OR-00-006, September 2000.

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DEPARTMENT OF OPERATIONS RESEARCH

Thesis Abstracts

THESIS ABSTRACTS

THE K-GROUP MAXIMUM-FLOW NETWORK-INTERDICTION PROBLEM

Ibrahim Akgun-First Lieutenant, Turkish Army

B.S., Turkish Army Military Academy, 1994

Master of Science in Operations Research-March 2000

Advisor: R. Kevin Wood, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

The K -group network-interdiction problem (KNIP) in which a "network user" attempts to maximize flow among $K \geq 3$ "node groups" while an "indicator" interdicts (destroys) network arcs, using limited interdiction resources, to minimize this maximum flow was studied. Two models were developed to solve or approximately solve KNIP.

The multi-partition network-interdiction model (MPNIM) is an approximating model. It partitions the node set N into K different subsets, each containing one prespecified node group, and interdicts arcs using limited resources so that the total capacity of uninterdicted arcs crossing between subsets is minimized. The multi-commodity network-interdiction model (MCNIM) explicitly minimizes the maximum amount of flow that can potentially be moved among node groups using K single-commodity flow models connected by joint capacity constraints. It is a min-max model but is converted into an equivalent integer program MCNIM-IP.

Both MPNIM and MCNIM-IP are tested using four artificially constructed networks with up to 126 nodes, 333 arcs, $K=5$, and 20 interdictions allowed. Using a 333 MHz Pentium II personal computer, maximum solution times are 563.1 seconds for MPNIM but six of 16 MCNIM-IP problems cannot be solved in under 3,600 seconds.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Command, Control, and Communications, Electronics Warfare, Modeling and Simulation

KEYWORDS: Network Interdiction, Minimizing Maximum Flow, Node Isolation, Integer Program

ANALYSIS OF THE DETERIORATION RATE OF SHIP HANDLING PROFICIENCY OF SURFACE WARFARE OFFICERS ON SHORE DUTY

Brad A. Alaniz-Lieutenant, United States Navy

B.S., United States Naval Academy, 1994

Master of Science in Operations Research-June 2000

Advisor: William K. Krebs, Department of Operations Research

Second Reader: Thomas W. Lucas, Department of Operations Research

This thesis examines the deterioration of ship handling proficiency of Surface Warfare Officers on shore duty. A Surface Warfare Officer (SWO) develops ship handling proficiency during his or her first and second ship tours, then spends two or more years ashore. Upon returning to sea duty, an officer is expected to be proficient in ship handling even though it has been two years since the last shipboard evolution. Ashore SWOs were tested to determine whether their ship handling skills or knowledge about navigation rules had degraded over time. During the first phase of the experiment, subjects were immersed in a virtual environment to assess procedural knowledge of a ship handling task. The second phase of the experiment, designed to measure declarative knowledge of ship handling handling, consisted of a short written test. The results of the experiment showed no deterioration of SWOs ship handling skills over time. The results did show a significant deterioration of declarative knowledge of navigation rules. Actual or potential applications of this research include revising current Surface Warfare Officer training programs to account for the fact that not all knowledge is lost to memory equally. Periodic refresher training for SWOs on shore duty is also suggested by these results.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Human Systems Interface, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Manpower, Personnel, and Training

THESIS ABSTRACTS

AN ANALYTICAL COMPARISON OF HUMAN FACTOR MAINTENANCE RELATED PART FAILURES FOR NAVAL RESERVE FLEET LOGISTICS SUPPORT WING

Daniel L. Allen-Lieutenant Commander, United States Navy

B.A., Wittenberg University, 1985

Master of Science in Management-December 1999

Advisors: CDR Kevin J. Maher, USN, Department of Operations Research

CDR John K. Schmidt, USN, School of Aviation Safety

Second Reader: Donald R. Eaton, Department of Systems Management

Naval Aviation has experienced extensive change in recent years. Financial constraints, force reductions, and increasing operation tempo have impacted not only the material condition of Naval aircraft, but also the personnel who maintain them. The Naval Aviation Community has extensively studied the role of human factors in aviation mishaps. However, the need to study the impact of human factors in maintenance on part failures remains. As replacement parts for aircraft continue to rise in price, the need to mitigate the unnecessary failure/destruction of piece parts is an ever increasing priority. This study examines the relationship between part failures and human factors by comparing incident rates between VR Wing with the rest of Naval Aviation. Five hundred safety incident reports are analyzed; fiscal year totals are determined, and an incident per flying hour rate is computed. Regression results indicate an increasing trend in human factors related parts incidents; VR compares no different from the rest of Naval Aviation.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Human Systems Interface

KEYWORDS: Aviation Mishaps, Material Failures, Hazard, Human Factors, Human Error, Accident Classification, Maintenance Mishaps, Regression Analysis

A COST MODEL FOR ESTIMATING OPERATING AND SUPPORT COSTS FOR UNITED STATES NAVY (NUCLEAR) SUBMARINES

William J. Allison-Lieutenant Commander, United States Navy

B.S., Eastern Washington University, 1987

Master of Science in Operations Research-June 2000

Advisor: LCDR Timothy P. Anderson, USN, Department of Operations Research

Second Reader: Samuel E. Buttrey, Department of Operations Research

This thesis attempts to formulate a parametric cost model to estimate the annual operating and support (O&S) cost of future U.S. Navy (nuclear) submarines, based on presumed physical characteristics and manpower expectations. Source data for the analysis is obtained from the Navy's VAMOSC database. Using regression analysis techniques, cost estimating relationships are developed for three assumed cost drivers - manpower, length, and submerged displacement. However, the analysis reveals that there is no significant relationship between annual O&S cost and the three assumed cost drivers. Therefore, an alternative method of estimating annual O&S cost is presented using probabilistic assessment of cost based on the empirical annual O&S cost distribution. The probabilistic assessment method allows decision-makers and cost analysts to estimate the annual O&S cost for which there is a desired probability that the true annual O&S cost of a new submarine will not be exceeded. For example, historically, 80 percent of all SSNs have experienced annual O&S costs of less than \$27 M (CY99\$), while the remaining 20 percent have experienced annual O&S costs greater than \$27 M (CY99\$). So, loosely speaking, one can be approximately 80 percent confident that the annual O&S cost of a newly acquired SSN will be no more than \$27 M (CY99\$). Similar results can be obtained for any SSN or SSBN, and for any desired probability.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Other (Cost Estimation)

KEYWORDS: Government, Cost Estimating, Submarines, Operating and Support, Statistics/Regression

THESIS ABSTRACTS

AN INTELLIGENT AGENT SIMULATION OF SHIPBOARD DAMAGE CONTROL

Sylvio F. Andrade-Lieutenant Commander, Brazilian Navy

B.S., Brazilian Naval Academy, 1987

Master of Science in Operations Research-June 2000

Advisors: Neil C. Rowe, Department of Computer Science

Donald P. Gaver, Jr., Department of Operations Research

Second Reader: Patricia A. Jacobs, Department of Operations Research

A fire on board a ship presents special challenges. It requires not only special anti-fire devices but well-trained teams of firefighters. Since crews rotate periodically, there is a need for ongoing personnel training and not all crew members have the same amount of training. A significant problem is how to assess the effectiveness of a team of firefighters with different skills in a real situation. A team should work together efficiently and follow standard procedures correctly if it is to successfully extinguish the fire within a reasonable period of time and with minimum damage. The question is: What skills are of most importance to a successful team of firefighters? It is difficult to carry out physical experiments without risking human lives and material losses. This thesis uses a reactive agent-based simulation to study the importance of different firefighting skills and anti-fire devices to the prosecution of fire on board a ship.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human Systems Interface

KEYWORDS: Artificial Intelligence, Fire, Firefighters, Firefighting Skills, Anti-Fire Devices, Stochastic Modeling

THE RELATIONSHIP BETWEEN A SUBMARINE'S MAXIMUM SPEED AND ITS EVASIVE CAPABILITY

Knut Rief Armo-Commander, Royal Norwegian Navy

B.S., Royal Norwegian Naval Academy, 1986

Master of Science in Operations Research-June 2000

Advisor: Arnold H. Buss, Department of Operations Research

Second Reader: James N. Eagle, Department of Operations Research

The experiences of submarine warfare from WWI and WWII have generally dictated maximum speed when designing conventional submarines. Technological development of submarine and anti-submarine weapons, however, requires examination of submarine warfare and tactics. This thesis focuses on a coastal conventional submarine's ability to survive, as a function of its maximum speed, when attacked by a light anti-submarine warfare (ASW) torpedo. It also evaluates the maximum speed with which the submarine should be equipped to ensure a specified probability of survival. The measure of effectiveness (MOE) is the probability that the submarine, operating up to maximum speed and launching only one set of countermeasures, is not caught by the torpedo.

The investigation builds on a discrete event simulation model. The systems simulated are a submarine, a light ASW torpedo, and a countermeasure system consisting of one decoy and four jammers. The results show that maximum speed of a submarine does effect the submarine's evasive performance between 12 and 18 knots. The simulated model reached a maximum probability of survival at 18 knots. That result should be regarded as a minimum since a real life system might require a higher maximum speed to reach its greatest probability of survival.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Conventional Submarines, Anti-Submarine Warfare Torpedoes, Torpedo Countermeasure Systems

THESIS ABSTRACTS

A FAST HEURISTIC FOR TOMAHAWK LAND-ATTACK PREDESIGNATION

Andrew Arnold-Lieutenant, United States Navy

B.S. Purdue University, 1991

Master of Science in Operations Research-June 2000

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

The Tomahawk Land-Attack Missile (TLAM) is a lethal, accurate, and long-range weapon that has provided the National Command Authority with the ability to respond with force to crises without committing troops or necessitating a large military build-up. When either the National Command Authority or regional Commander in Chief authorizes the use of TLAMs against specified targets, predesignation determines which ship or submarine will fire its missiles at which targets in support of the attack. This thesis presents a fast heuristic to predesignate TLAM target assignments to ships and submarines in multiple battle groups and launch areas over successive time periods. The heuristic allows tasks to be spread or restricted among firing units on a per-target basis, incorporates a variety of task types, and allows all or part of the target list to be manually prioritized. Additionally, the heuristic ensures that better solutions cannot be obtained through a simple, one-complement interchange.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles - Ships and Watercraft, Modeling and Simulation

KEYWORDS: Tomahawk Land-Attack Missile, Heuristic, Weapons Allocation

SCREEN DISPOSITIONS OF NAVAL TASK FORCES AGAINST ANTI-SHIP MISSILES

Erhan Aydin-Lieutenant Junior Grade, Turkish Navy

B.S., Turkish Naval Academy, 1994

Master of Science in Operations Research-March 2000

Advisor: Arnold H. Buss, Department of Operations Research

Second Reader: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

Ship defense in convoy operations against Anti-Surface Missiles (ASM) has been an important aspect of Naval Warfare for the last two decades. Countries in a state of conflict often conduct threatening operations in their own territories in order to slow or stop the enemy merchant ship traffic through the straits or littoral waters. Such littoral scenarios, the quantity and capability of ASMs in non-NATO countries pose a significant threat to the safe operation of the NATO forces in the waters off of potentially hostile shores. In these operations the goals of the tactical commander are to design an optimal reaction platform (formation) and to determine an optimal strategy that will help him in multi-threat encounters. The scope and design in most anti-air warfare studies have been limited to evaluating the effectiveness of detecting sensors and weapon systems in a regular screen formation. The proposed model's (Disposition Mission Model - DMM) characterization, however, is based on how to perform an effective, defensive disposition from a task force. In DMM we focus on usage of a graphical user interface and provide a user-friendly environment for analyzing new tactics in screen formations. The model, with its user interface, allows the user to build and run a convoy simulation, and see the results comparatively on the same interface. The analysis using this model has yielded significant insights towards the defense of a convoy by way of regression methods. It has been seen that positioning the escort ships within the threat sector reduces the damage on the HVU and also balances the defensive load of each defense ship for the incoming missiles. The model, with its graphical interface and simulation components, provides an initial approach for future analysts, not only in anti-air warfare defense of screen formations, but also in the areas of anti-surface and anti-submarine warfare.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human Systems Interface

KEYWORDS: Littoral Arena, Disposition, Tactics, Simulation, Graphical User Interface, Swing

THESIS ABSTRACTS

OPTIMALLY SCHEDULING EA-6B DEPOT MAINTENANCE AND AIRCRAFT MODIFICATION KIT PROCUREMENT

**Rosser O. Baker, Jr.-Major, United States Marine Corps
B.S., United States Naval Academy, 1984**

Master of Science in Operations Research-September 2000

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Alan R. Washburn, Department of Operations Research

The Department of the Navy maintains a fleet of 124 EA-6B aircraft, the only tactical electronic warfare aircraft in the Department of Defense inventory. Already 30 years old and not to be retired until 2015, the EA-6B requires depot maintenance services to remain combat ready. EA-6B aircraft undergo standard depot level maintenance (SDLM) about every eight years. In addition to SDLM, depots must complete 72 wing center section replacement services and over 175 major aircraft modification services by 2010. Navy regulations govern when each EA-6B is eligible for each service; these rules are flexible enough to allow more induction schedules than can be evaluated manually in a reasonable amount of time. Because each service keeps an aircraft at the depot for six to 14 months and performing multiple services together requires less time than performing services independently, services should be combined whenever possible.

This thesis introduces DMAAP (Depot Maintenance and Acquisition Planner); a prototypic optimization based decision support tool to assist in scheduling EA-6B depot level maintenance services and major aircraft modification kit acquisition. DMAAP produces a Master Plan (induction schedule) providing a monthly schedule for the first six years, a yearly schedule out to 2013 and yearly major aircraft modification kit acquisition levels out to 2010. We compare DMAAP Master Plans obtained using alternate depot induction policies to demonstrate DMAAP's ability and show how yearly depot workloads and yearly operational aircraft vary under alternate policies.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Integer Linear Programming, Aircraft Depot Maintenance, Optimization, EA-6B, SDLM (Standard Depot Level Maintenance)

OPTIMIZATION OF UNITED STATES MARINE CORPS OFFICER CAREER PATH SELECTION

**Peter B. Baumgarten-Major, United States Marine Corps
B.S., United States Naval Academy, 1988**

Master of Science in Operations Research-September 2000

Advisor: Siriphong Lawphongpanich, Department of Operations Research

Second Reader: Alexandra Newman, Department of Operations Research

The Marine Corps Manpower System is responsible for managing the Marine officer inventory. The system's primary objective is to maximize the Marine Corps' operational readiness through the assignment of officers to billets. While striving to fulfill billet requirements, the manpower system simultaneously develops the professional skills, or core competencies, that each officer must possess to be assigned to billets requiring more authority and responsibility. Therefore, officer careers (or career paths) must reflect a balance between fulfilling billet requirements and developing core competencies. Currently, MarineCorps manpower planners lack rigorous methods to assist them in understanding the effects of various personnel policy decisions on the average officer career path or the system's ability to meet future billet requirements.

To assist these planners, this thesis presents an integer program, the Officer Career Path Selection (OCPS) Model. The goal of OCPS is to assign officers to acceptable career paths in order to best meet billet requirements while satisfying, among others, core competency and tour length constraints. This thesis uses data from the Infantry Marine Occupational Specialty (MOS) to illustrate that outputs from OCPS provide useful information regarding the number of annual Infantry officer accessions and the effects of potential manpower policy decisions.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Manpower Planning, Optimization, Set-Covering

SOLVING DYNAMIC BATTLESPACE MOVEMENT PROBLEMS USING DYNAMIC DISTRIBUTED COMPUTER NETWORKS

Robert D. Bradford, III-Captain, United States Army

B.S.E., Princeton University, 1989

Master of Science in Operations Research-June 2000

Advisor: Gordon H. Bradley, Department of Operations Research

Second Reader: Arnold H. Buss, Department of Operations Research

This thesis develops an architecture for dynamic distributed military operations research. This architecture assumes that a network of heterogeneous computing devices connects forces throughout the battlespace. Both the raw data about the battlespace and the operations research models used to analyze this data are accessible to devices on this network. The thesis designs a system using this architecture that invokes operations research network optimization algorithms to solve problems involving movement of people and equipment over dynamic road networks. A specific application is implemented to help a medic find the nearest aid station using a shortest path algorithm. This application marshals the most current data on unit locations and road conditions (distributed across the computing network) and locates on the network an appropriate algorithm that is then used to construct a solution. The answer is returned to the user as a web page in a form appropriate for his computing device. The application is implemented with existing technologies including the Java computer language, König, a Java-based tool for representing networks and graphs, and Hypertext Markup Language, a format for shared information on the Internet. This system uses operations research tools to transform data into decisions in real-time or near real-time.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software

KEYWORDS: Computer Architecture, Network Optimization, Java, Loosely Coupled Components

AGENT BASED SIMULATION AS AN EXPLORATORY TOOL IN THE STUDY OF THE HUMAN DIMENSION OF COMBAT

Lloyd P. Brown-Captain, United States Marine Corps

B.S., University of Arizona, 1990

Master of Science in Operations Research-March 2000

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

War is a human phenomenon and the essence of war is a clash between human wills. The Marine Corps is applying complexity theory to study the human dimension of land warfare with the agent based combat simulation Irreducible Semi-Autonomous Adaptive Combat (ISAAC), developed by Andrew Ilachinski. ISAAC is designed to allow the user to explore the evolving patterns of large unit behavior that result from the collective interactions of individual agents. An urban and a desert scenario were developed to explore command and control issues with ISAAC. Utilizing a personal computer and the Maui High Performance Computer Center, approximately 750,000 ISAAC runs were completed. The data are analyzed and graphically displayed using S-Plus generated Design and Trellis plots. The ISAAC data suggests there is some optimal balance between a commander's propensity to move towards the objective and his propensity to maneuver to avoid the enemy in order to minimize time to mission completion and friendly losses. Also, the data suggest that friction can significantly influence the battlefield but a strong commander-subordinate bond can reduce the effect. The exploration also demonstrated that fractional factorial designs provide almost as much information from ISAAC as full factorial designs with only a fraction of the runs.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Human System Interface

KEYWORDS: ISAAC, Agent Based Simulation, Simulation, Human Dimension of Combat, Combat Models

CASE STUDY OF THE UNITED STATES MARINE CORPS ADVANCED AMPHIBIOUS ASSAULT VEHICLE (AAAV) PROGRAM TEST AND EVALUATION STRATEGY

**Brian K. Buckles-Major, United States Marine Corps
B.S., University of Idaho, 1987**

Master of Science in Management-December 1999

**Advisors: Thomas H. Hoivik, Department of Operations Research
Orin E. Marvel, Command, Control, Communications, Computers, and
Intelligence Academic Group**

This thesis examined the evolution of the direct reporting program manager-advanced amphibious assault's test and evaluation strategy from milestone 0 to the present. The research effort involved reviewing the evolution of amphibious doctrine and amphibious vehicles, reviewing the DoD acquisition process and the role of T&E in that acquisition process, and analyzing three DRPM-AAA test and evaluation master plans. Interviews were conducted with personnel from the DRPM-AAA office and general dynamics amphibious systems. Additionally, program documents and acquisition literature were reviewed. An analysis of test and evaluation issues facing the program management office, a determination of the effects those issues had on the program's test strategy, and applicable lessons learned are documented for use by other major defense acquisition programs. Key research findings conclude: that the DRPM-AAA's T&E strategy remained stable and consistent from milestone 0 to the present as a result of the continuity of the AAAV's key performance parameters; that the DRPM's decision to develop a working relationship that "actively engages" both oversight and external agencies early in the test planning process serves in achieving test resource efficiencies; and that the IPT decision-making process differs significantly from the more formal "staff planning process" used by most military organizations.

DoD KEY TECHNOLOGY AREAS: Ground Vehicles, Other (Amphibious Warfare, Test and Evaluation)

KEYWORDS: United States Marine Corps, AAAV, Advanced Amphibious Assault Vehicle, DRPM-AAA, Major Defense Acquisition Program, Test and Evaluation, Developmental Testing, Operational Testing

A MULTIVARIATE TIME SERIES ANALYSIS OF U.S. ARMY RECRUITING

**Eric C. Burger-Captain, United States Army
B.S., United States Military Academy, 1990**

Master of Science in Operations Research-June 2000

**Advisor: Samuel E. Buttrey, Department of Operations Research
Second Reader: Lyn R. Whitaker, Department of Operations Research**

The United States Army Recruiting Command requires tools to quantify the impact of factors in the recruiting environment, identify differences in the recruiting processes across its five regional subordinate units, and measure the effectiveness of its policies and resource expenditures. This thesis examines recruiting data for the "high-quality" male demographic from July 1992 to September 1997. It uses multivariate time series analysis to predict the number of enlistment contracts signed in a month as a function of fifteen exogenous and endogenous factors plus monthly indicators. A stepwise recursion using bootstrap simulation is developed to identify significant factors in the multivariate time series. The significant factors in the reduced models are compared to those contained in models developed in previous studies. The models are also used to create nine-month projections of recruiting production, which are compared to known production figures from test set data to determine forecast accuracy. The results of this

THESIS ABSTRACTS

research support the intuition that the influential factors differ by region. The stepwise model reduction recursion using bootstrap simulation offers potential for further refinement and application.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Time Series, Bootstrap, Recruiting, Operations Research

AN ANALYSIS OF PURCHASE CARD RECONCILIATION TIMES

Michele M. Burk-Lieutenant Commander, United States Navy

B.S., University of Michigan, 1987

Master of Science in Operations Research-December 1999

Advisor: Lyn R. Whitaker, Department of Operations Research

Second Reader: William R. Gates, Department of Systems Management

Effective 1 October 1997, the Government Commercial Purchase Card was mandated for micro-purchases of commercial items (procurement valued at or below \$2,500). As of August 1999, 97% of Navy activities use purchase cards for micro-purchases. During fiscal year 1998, these activities used the purchase card in over 1,996,000 transactions valued at \$1.055 billion dollars. Overall, purchase card implementation has been an overwhelming success, drastically reducing administrative costs and providing a streamlined procurement process. Even though efforts have been made to refine the reconciliation process to help government activities avoid unnecessary interest payments, there are still many potential improvements. The government purchase card is similar to standard issue credit cards, so interest accrues on delinquent invoices. During the fourth quarter of fiscal year 1999, the U.S. Navy paid \$323,000 in interest payments due to delinquent invoices. Of this total, the activities under CINCLANTFLT were responsible for \$58,000 and those under CINCPACFLT were responsible for \$43,000. A combination of data analysis and systems analysis techniques are used to define the reconciliation process, to suggest process improvements, and to recommend tools to better manage the reconciliation process.

DoD KEY TECHNOLOGY AREA: Other (Financial Reconciliation)

KEYWORDS: Government Purchase Cards, IMPAC Card, Statistical Process Control

SERVICE LEVEL OPTIMIZATION FOR THE MARINE CORPS INSTITUTE

Gregory F. Chapman-Lieutenant, United States Navy

B.S., United States Naval Academy, 1993

Master of Science in Operations Research-June 2000

Advisor: CDR Kevin J. Maher, USN, Department of Operations Research

Second Reader: David A. Schrad, Department of Operations Research

The Marine Corps Institute (MCI) is the distance learning center for the United States Marine Corps. MCI's mission is to develop, publish, distribute, and administer distance training and education materials to enhance, support, or develop required skills and knowledge of Marines. It also satisfies other training and education requirements as identified by the Commanding General, Marine Corps Combat Development Command.

To meet this mission MCI develops and assembles course materials ranging from simple training courses to college level Professional Military Education (PME) programs. Each course or program consists of multiple components that must be printed, stocked, and distributed to all Marines. Currently MCI offers 151 courses comprised of 305 printed components. In 1999 MCI processed over 550,000 requests for course materials.

In late 1998 MCI recognized the need to improve their inventory control processes. They desired a means of determining reorder points and reorder quantities for the Marine Corps Institute in order to improve service to Marines in the field. This thesis develops a non-linear program inventory model that minimizes the number of shortages per year, and returns reorder points and reorder quantities, thereby improving MCI's service to the Marine Corps.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Other (Inventory Policy, Optimization)

KEYWORDS: Marine Corps Institute, Inventory Policy, Optimization

COST AND OPERATIONAL EFFECTIVENESS ANALYSIS OF ALTERNATIVE FORCE STRUCTURES FOR FULFILLMENT OF THE UNITED STATES MARINE CORPS OPERATIONAL SUPPORT AIRLIFT AND SEARCH AND RESCUE MISSIONS

Eric T. Chase-Major, United States Marine Corps

B.S., United States Naval Academy, 1986

Master of Science in Management-March 2000

Advisors: Thomas H. Hoivik, Department of Operations Research

LCDR Timothy P. Anderson, USN, Department of Operations Research

William R. Gates, Department of Systems Management

This thesis provides a preliminary cost and operational effectiveness analysis of alternative force structures for the United States Marine Corps operational support airlift and search and rescue missions. The four alternative force structures include C-12s and CH-46Es, C-35s and CH-46Es and HV-609s. Lifecycle cost analysis of the alternative force structures using Crystal Ball forecasting provides a 90% upper confidence level lifecycle cost estimate that identifies a mix of C-35s for operational support airlift and CH-46Es for search and rescue as the least expensive alternative. Operational effectiveness analysis provides a measure of overall utility for each of the four alternative force structures based on five measures of effectiveness. The measures of effectiveness examined are air travel time, total travel time, landing site requirements, range versus time on station, and payload versus range. Analytical hierarchy process rankings indicate that the HV-609 is the preferred alternative considering these measures of effectiveness. Analysis of cost versus operational effectiveness identifies the HV-609 as the most cost and operationally effective alternative for fulfilling the Marine Corps operational support airlift and search and rescue missions.

DoD KEY TECHNOLOGY AREA: Air Vehicles

KEYWORDS: Tiltrotor, Operational Support Airlift (OSA), Search and Rescue (SAR), Cost and Operational Effectiveness Analysis (COEA), C-12, C-35, CH-46E, HV-609

USING NEURAL NETWORKS WITHIN THE LEAVES OF A CLASSIFICATION TREE

Chia-Sheng Chen-Lieutenant Colonel, Taiwan Army, Republic of China

B.S., Chinese Military Academy, 1986

Master of Science in Operation Research-June 2000

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

Classification trees and neural networks are widely used individually, yet little is known about the effect of combining these two techniques. Earlier work has shown that using k -nearest neighbor (k -NN) inside the leaves of a tree can increase classification accuracy. Since neural networks are so powerful, we apply neural networks instead of the k -NN method inside the leaves of the tree.

This thesis studies the performance of this composite classifier. It is compared to the tree-structured classifier and the neural network classifier. We use commonly available data sets in this application and compare the results to those generated by other generally used classifiers.

Compared to the results of the other two classifiers in this thesis, the composite classifier always gives the lowest cross-validated misclassification error rates in these data sets. Its excellent performance tells us that it is worth further investigation.

DoD KEY TECHNOLOGY AREA: Other (Statistics)

KEYWORDS: Classification Tree, Neural Networks, Nnet.in.leaf Method, Cross-validation, Misclassification Rate

THESIS ABSTRACTS

AN ANALYSIS OF THE IMPACT OF FULLY FUNDED GRADUATE EDUCATION ON THE RETENTION OF NAVAL OFFICERS

Eric L. Conzen-Lieutenant, United States Navy

B.S., United States Naval Academy, 1993

Masters of Science in Operations Research-December 1999

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Robert A. Koyak, Department of Operations Research

This thesis investigates the impact of "funded graduate education" on retention of Naval Officers. Logit regression and multivariate models were used to determine the effects that a graduate degree from the Naval Postgraduate School (fully funded) or civilian graduate schools through partially funded graduate programs had on officer retention. The data sets were created using data from the Officer Master Record Files (OMRF) obtained from the Defense Manpower Data Center, Monterey, California (DMDC). The data sets included all Naval Officers that were eligible for voluntary separation each year from 1992 to 1997.

Maximum likelihood logit regression was used to estimate the probabilities that officers with graduate degrees earned from NPS or civilian institutions decide to leave the service at the end of any mandatory educational obligation. The findings revealed indicate that although funded graduate education may have an effect on promotion possibilities, its impact on retention past the ten-year point in an officer's career is not detectable.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Graduate Education, Retention, Subspecialty, Postgraduate Degree

HUMAN FACTORS ANALYSIS OF FISCAL YEAR 90 TO 97 ROTARY WING AND TACAIR FLIGHT MISHAPS

Kenneth R. Denham-Lieutenant, United States Navy

B.S., Florida State University, 1992

Master of Science in Operations Research-June 2000

Advisor: CDR John K. Schmidt, USN, School of Aviation Safety

Second Reader: Lyn R. Whitaker, Department of Operations Research

Human error is present in approximately 60 to 80 percent of all Naval Aviation (NA) flight mishaps (FMs). This indicates a need to identify the patterns and relationships of human error associated with NA FMs in order to develop tailored intervention strategies. This study uses the Human Factors Analysis and Classification System (HFACS), a human error oriented accident investigation and analysis process, to conduct post-hoc analysis of 77 rotary wing and 141 Tactical Aircraft (TACAIR) Class A and B human error FMs from Fiscal Year 90 to 97. This study indicates that Skill-Based Error, Decision Error, Adverse Mental State (AMS) and Crew Resource Management (CRM) are the predominant human error types associated with NA FMs. A nonparametric bootstrap simulation is performed for singular and combinations of human error types to develop the most effective intervention strategies. For the rotary wing community, the CRM human error type represents the best target for selected intervention strategies and potential cost savings. The AMS human error type provides the best target for selected intervention strategies and potential cost savings for the TACAIR community. The use of flight simulators is viewed as the most effective intervention strategy for both predominant human error types identified.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Manpower, Personnel and Training, Modeling and Simulation, Other (Accident Analysis)

KEYWORDS: Naval Rotary Wing Mishaps, Naval Tactical Aircraft Mishaps, Human Factors, Human Error, Accident Classification, Accident Prediction, Poisson Process, Modeling, Simulation, Accident Analysis

THESIS ABSTRACTS

ASSIGNING UNMANNED UNDERSEA VEHICLES TO MINE DETECTION OPERATIONS

J. Enrique Reyes Diaz-Lieutenant, United States Navy

B.S.E., University of Michigan, December 1991

Master of Science in Operations Research-December 1999

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Donald Brutzman, Undersea Warfare Academic Group

In an era when mines are inexpensive and easily accessible, present and near-term mine detection and area reconnaissance capabilities are insufficient to enable unencumbered maneuver in the littoral regions. Unmanned undersea vehicles (UUVs) possess potential to provide tactical commanders with full understanding of the mine threat without risk to ships or personnel and without exposing intentions. By integrating an assortment of emerging capabilities, a system comprised of a variety of UUVs could address this growing mine threat. This thesis develops and implements the Mine Reconnaissance System Assessment (MiRSA) model, a mixed integer-linear program to assign a mix of UUVs to search areas within a suspected minefield area. This thesis compares combinations of two Long-term Mine Reconnaissance System (LMRS) vehicles, six Remote Environmental Monitoring Units (REMUS) vehicles, and a notional Manta vehicle searching a 262 square nautical mile area in the Straits of Hormuz. MiRSA finds the two LMRS vehicles can complete a 95% confidence level search in 91 hours, the Manta vehicle can complete the search in 130 hours, and the two LMRS vehicles with Manta employed optimally together require only 52 hours. At a 99.99% confidence level search, Manta operating alone requires 298 hours (approximately 12 days) while optimal employment of the two LMRS, six REMUS, and Manta vehicles together can finish the search in only 104 hours.

DoD KEY TECHNOLOGY AREA: Other (Unmanned Undersea Vehicles)

KEYWORDS: Unmanned Undersea Vehicle, Long-term Mine Reconnaissance System, Remote Environmental Monitoring Units, Manta, Mine Detection

CAMPAIGN ANALYSIS OF A NATO GROUND FORCES CAMPAIGN IN KOSOVO

Armin D.W. Dirks-Captain, German Army

M.S., Bundeswehr University Hamburg, 1986

Master of Science in Operations Research-June 2000

Advisors: Thomas W. Lucas, Department of Operations Research

James G. Taylor, Department of Operations Research

Second Reader: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

On March 24, 1999, the North Atlantic Treaty Organization (NATO) started an air campaign by attacking targets in Serbia, including Kosovo. This thesis analyzes the question: "What might have happened if Serbia had not retreated and NATO had to conduct a ground forces campaign to achieve its objectives?"

The aggregated combat model uses the situational force scoring (SFS) methodology, introduced by RAND, to compute force ratio, attrition, and movement as the result of combat. For a portion of the campaign analysis, the General Campaign Analysis Model (GCAMTM), developed by *Systems Planning and Analysis, Inc.*, is used.

It is shown that a NATO ground forces campaign in Kosovo will only be successful, if tactical and technological measures can reduce significantly the defender's use of anti-tank (AT) weapons; even then, the casualties on the attacker's side are relatively high. Furthermore, the developed model is a starting point for the development of a decision support tool for joint contingency planning in higher HQ.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Campaign Analysis, Ground Forces, Kosovo/Serbia/Yugoslavia, RAND, Situational Force Scoring (SFS) Methodology, GCAMTM

THESIS ABSTRACTS

COMPARISON STUDY OF JANUS AND HLA WARRIOR

Dixon D. Dykman-Captain, United States Army

B.S., United States Military Academy, 1991

Master of Science in Operations Research-June 2000

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: MAJ Gerald M. Pearman, USA, TRADOC Analysis Center-Monterey

The Training & Doctrine Command (TRADOC) Analysis Center (TRAC) – Monterey, California re-engineered the Janus simulation as a technology demonstration. The completed simulation, HLA Warrior, applied modern technologies including an object-oriented design and state-of-art user interfaces. The project also re-wrote Janus source code in C++. The purpose of this thesis was to assess HLA Warrior's fidelity, defined as its ability to replicate Janus results, by conducting a statistical comparison of Janus and HLA Warrior. Given that Janus has high "face-validity," Janus results acted as the baseline from which HLA Warrior results were compared. The comparison involved executing identical scenarios in Janus and HLA Warrior, gathering results, and conducting a rigorous statistical comparison of Janus and HLA Warrior results. Statistical tests included the paired *t*-test and non-parametric Wilcoxon Signed Ranks Test.

Results from the tests showed differences between Janus and HLA Warrior. Investigation into the causes of the differences found two source code errors in HLA Warrior. Re-evaluation of HLA Warrior following correction of the errors resulted in a reduction in magnitude of the differences. Probable causes due to algorithm implementation differences were also identified. While differences exist, HLA Warrior appears to have face-validity and generally produces outcomes similar to Janus.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Janus, HLA Warrior, Statistical Validation, Simulation

ASSESSMENT OF SHALLOW WATER INFLUENCE MINESWEEPING SYSTEM (SWIMS) IMPLEMENTATION UTILIZING CH-60

James K. Edwards-Lieutenant, United States Navy

B.Che., Villanova University, 1991

Master of Science in Operations Research-December 1999

Advisor: Kneale T. Marshall, Department of Operations Research

Second Reader: George W. Conner, Department of Operations Research

The Sikorsky H-60 airframe is planned to be the only rotary-wing aircraft in the Navy's inventory through 2015. The CH-60 variant will support the Airborne Mine Countermeasures (AMCM) mission, replacing the current MH-53E and it's MK-106 towed influence system. The CH-60's towing capacity will be significantly less than the MH-53E, so new equipment, designated the Shallow Water Influence Mine Sweeping (SWIMS) system. Capability of SWIMS is expected to be significantly less than that of the MK-106 system. Smaller size and aircraft commonality will enable SWIMS to deploy on most surface combatants, providing forward presence and reducing employment time of an AMCM suite into a Mine Danger Area (MDA).

The purpose of this study is to analyze the feasibility of, and the trade-off possibilities for, different types of AMCM operations using the CH-60 and SWIMS system. Given the planned limited capabilities of the CH-60/SWIMS system relative to the MH-53E/MK-106 system, we explore methods for determining; (i) how to operate CH-60/SWIMS using proposed new employment methods, (ii) how many CH-60's will be required to clear a specified MDA, and (iii) how to minimize the operational impact to the ships involved.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Sensors

KEYWORDS: Airborne Mine Countermeasures, Helicopter Employment Techniques, Decision Making and Forecasting, Use of Force Modeling

THESIS ABSTRACTS

DESIGN AND ANALYSIS OF A SHIPBOARD VISUAL NAVIGATION AID FOR VESSELS IN FORMATION

**Thomas V. Evanoff-Lieutenant Commander, United States Navy
B.S., Illinois Institute of Technology, 1987**

Master of Science in Operations Research-December 1999

Advisor: William K. Krebs, Department of Operations Research

Second Reader: Rudolph P. Darken, Department of Computer Science

This thesis examines the development and analysis of a specialized lighted visual navigation aid, called Tactical Vectoring Equipment (TVE), designed to assist shipboard conning officers when maneuvering in a battle group formation. Piloting at night in close proximity to another vessel can be one of the most challenging and dangerous evolutions at sea. In particular, one of the most demanding tasks is nighttime plane-guard duty. During this evolution, the conning officer utilizes voice radio communications, radar, and visual navigation aids to maintain proper station astern of an aircraft carrier and make maneuvering decisions. However, these visual cues and navigational aids can be ambiguous or late. Conning officers can experience situational disorientation with their attention distributed between tracking the carrier and other bridge duties. At night, the loss of contrast sensitivity, the lack of daytime visual cues and confusing ship silhouettes can hinder determination of range, course, speed and target angle. A virtual environment computer model was used to design the specialized navigation aid and measure its effectiveness on subjects. The TVE light display resulted in significantly less range and bearing errors compared to normal navigation lights. This reduced human error, improved ship-handling accuracy and enhanced situational awareness. This is an effective, versatile, and inexpensive device that should be seriously considered for future development and implementation in the fleet.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Sensors, Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Visual Navigation Aid, Navigation Lights, Plane Guard Duties, Night Vision, Human Performance

WHO RESPONDS AND HOW LONG DOES IT TAKE: ASSIGNING FIRE STATION AREAS OF RESPONSIBILITY

James A. Evans-Major, United States Marine Corps

B.S., United States Naval Academy, 1983

M.S.B.A., Boston University, 1990

Master of Science in Operations Research-June 2000

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: R. Kevin Wood, Department of Operations Research

The city of Monterey, California, provides fire protection and emergency medical response (FP&EMR) for the city of Monterey, an Army facility and two adjoining communities. The city currently maintains three full-time fire stations. Within the city's boundaries lies the U.S. Naval Postgraduate School (NPS), which currently provides its own FP&EMR, but the city is evaluating the possibility of providing this service for NPS. This thesis develops models to predict response times from NPS and city stations to emergency locations and combines these models with an optimization model to evaluate how optimal response times would vary with and without the NPS station. Results indicate that the city would marginally satisfy federal response-time requirements for NPS by operating only its current three stations: Average response is acceptable, but the variance is not. However, if the city operates the NPS station and only two of its current stations, estimated response times improve over the status quo, and variance is acceptable. Based on data for one year, city operation of all four stations would provide a 7.5% reduction in total estimated response time compared to the status quo, while using two stations plus the NPS station would provide a 4.9% reduction.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Optimization, Integer Linear Program, P-Median Model

PLANNING CAPITAL INVESTMENTS IN NAVY FORCES

Richard J. Field-Lieutenant, United States Navy

B.S., Texas A&M University, 1992

Master of Science in Operations Research-December 1999

Advisor: Robert F. Dell, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

Naval spending has always involved large amounts of resources, research and technology, money, and the attention of civilian and military leadership. In 1794 the Congress authorized \$800,000 (1794 dollars) to construct six frigates. Today, an attack submarine costs more than \$2 billion, an aircraft carrier more than \$5 billion, and its air wing \$5 billion more. These ships are the only current American clients for nuclear power plants. The Navy must balance these large capital expenditures with other procurements and maintain an industrial base capable of producing these unique warships. The Navy currently manages these complex interplays via the Integrated Warfare Architecture Assessment Planning Process (IWARS). Force Structure, an IWARS component, views a 25-year horizon at the platform level using the Extended Planning Annex/Total Obligated Authority Model (a spreadsheet model that estimates the financial impact of any complete future plan). This thesis presents an integer-linear program, the Capital Investment Planning Aid (CIPA), that extends EPA/TOA with optimization. CIPA explores all alternatives while considering budget restrictions, industrial base requirements and restrictions, and force level requirements. CIPA is tested with a 25-year planning horizon with eight mission areas, 19 ship classes, five aircraft types, five production facilities, and three categories of money. A current base case and several excursions demonstrate CIPA can be used to address exigent issues optimally.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Operations Research, Integer Programming, Procurement, Capital Investments, Military Capital Budgeting, Optimization

PROTECTING THE FORCE: APPLICATION OF STATISTICAL PROCESS CONTROL FOR FORCE PROTECTION IN BOSNIA

Paul J. Finken-Captain, United States Army

B.S., United States Military Academy, 1989

Master of Science in Operations Research-June 2000

Advisor: LTC David Olwell, USA, Department of Operations Research

Second Reader: Thomas W. Lucas, Department of Operations Research

Military commanders determine the appropriate Force Protection measures to protect their units from a wide variety of threats based on their assessment of the enemy threat in the specific situation. They currently have no statistical tool from which to base their assessment of the threat, or to recognize changes in the current situation. In Operations Other Than War (OOTW), environments where the enemy is disorganized and incapable of mounting a deception plan, staffs could model hostile events as stochastic events and use statistical methods to detect changes to the process. This thesis developed a statistical tool, based on Cumulative Sum (CUSUM) and Shewhart Charts, that military leaders can use in OOTW environments to recognize statistically significant changes in the situation. The tool applies current univariate control chart methods, as well as an original nonparametric multivariate control scheme developed in this thesis, to North Atlantic Treaty Organization (NATO) Stabilization Force (SFOR) incident data. The tool enables commanders to identify isolated and persistent shifts in the means of the data categories or shifts in the correlation of three data categories. By recognizing changes in the current situation, military leaders have a basis from which to change their force protection measures and better protect their unit.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Other (Force Protection)

KEYWORDS: Statistical Process Control, Multivariate, Force Protection

AN EVALUATION OF SEA-BASED SUSTAINMENT OF FORCES

Christopher M. Frey-Captain, United States Marine Corps

B.S., United States Naval Academy, 1994

Master of Science in Operations Research-September 2000

Advisor: David A. Schrady, Department of Operations Research

Second Reader: Steven E. Pilnick, Department of Operations Research

The Marine Corps has formed a vision of how to conduct future amphibious warfare through its development of Operational Maneuver From the Sea (OMFTS), Ship-to-Objective Maneuver (STOM), and Sea-Based Logistics (SBL) concepts. These concepts have forces deploying directly from ship to objectives ashore with a reduction or elimination of logistics infrastructure ashore. Combat forces operating ashore will be sustained directly from a sea-base with support from ship-to-shore transporters. By sea basing logistics functions, there will be a much greater demand upon these transporters. This thesis models the sea-based sustainment of Marine Expeditionary Brigade (MEB) forces deployed from amphibious warfare ships. A scenario for analysis is developed with force packages of personnel and equipment located at certain locations ashore during different days of an operation. Sustainment requirements and available transporter capacity are then determined and compared for twenty-seven cases comprising different ship-to-shore distances, different levels of aircraft attrition due to enemy interdiction, and different footprints of mobile logistics forces deployed ashore. This comparison provides insight into the ability of SBL to sustain forces ashore conducting operations in accordance with OMFTS and STOM concepts.

DoD KEY TECHNOLOGY AREA: Other (Logistics)

KEYWORDS: Operational Maneuver From The Sea (OMFTS), Ship-to-Objective Maneuver (STOM), Sea-Based Logistics (SBL)

AGE REPLACEMENT POLICIES IN MULTIPLE TIME SCALES

Scott G. Frickenstein-Captain, United States Air Force

B.S., United States Air Force Academy, 1990

M.S., Florida State University, 1991

Doctor of Philosophy in Operations Research-June 2000

Dissertation Supervisor: Lyn R. Whitaker, Department of Operations Research

Committee Members: Robert R. Read, Department of Operations Research

Gerald G. Brown, Department of Operations Research

Samuel E. Buttrey, Department of Operations Research

Robert A. Koyak, Department of Operations Research

Craig W. Rasmussen, Department of Mathematics

We develop and estimate optimal age replacement policies for devices whose age is measured in multiple time scales. For example, the age of a jet engine can be measured in chronological time, the number of flight hours, and the number of landings. Under a single-scale age replacement policy, a device is replaced at age τ or upon failure, whichever occurs first. We show that a natural generalization to $k \geq 2$ scales is to replace non-failed devices when their usage path crosses the boundary of a k -dimensional region M , where M is a lower set with respect to the matrix partial order. For lifetimes measured in two scales, we consider two contexts. In the first, devices age along linear usage paths. For this case, we generalize the single-scale long-run average cost and estimate optimal two-scale policies. We show these policies are strongly consistent estimators of the true optimal policies under mild conditions, and study small-sample behavior using simulation. For the second context, in which device usage paths are unknown, we use two-

THESIS ABSTRACTS

dimensional renewal theory to derive the long-run average cost of a policy. We give examples in both settings and note that these ideas generalize to more than two scales.

DoD KEY TECHNOLOGY AREA: Other (Reliability)

KEYWORDS: Age Replacement, Multiple Time Scales, Renewal Theory

MODELING AND ANALYSIS OF HUMAN ERROR IN NAVAL AVIATION MAINTENANCE-RELATED MISHAPS

Ashley D. Fry-Captain, Australian Army

M.B.A., Deakin University, 1996

B.S., Queensland University of Technology, 1990

Master of Science in Operations Research-June 2000

Advisor: CDR John K. Schmidt, USN, School of Aviation Safety

Second Reader: Samuel E. Buttrey, Department of Operations Research

This study investigates human error associated with 599 Naval Aviation maintenance-related mishaps (MRMs) in Fiscal Years 90-99. The Human Factors Analysis and Classification System Maintenance Extension (HFACS-ME) taxonomy was utilized to classify contributory human errors within a robust theoretical framework. Variable Poisson process models are developed to predict MRMs and relationships between the error dimensions are investigated. The results of this study show that the HFACS-ME taxonomy provides an adequate framework for the classification of MRM causal factors; that variable Poisson process models are suitable for predicting future mishaps; and that there are significant relationships between selected causal dimensions; sufficient to warrant further investigation. These results provide information regarding the predicted impact of MRMs on future operational readiness and mission capability. Through being aware of these aspects, decision-makers are armed with the knowledge to make better decisions concerning the preservation and allocation of the resources at their disposal.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Manpower, Personnel, and Training, Modeling and Simulation, Other (Aviation Safety)

KEYWORDS: Aviation Accidents, Aviation Mishaps, Accident Classification, Accident Prediction, Maintenance Mishaps, Maintenance Error, Human Factors, Human Error, Poisson Process, Naval Aviation, Trend Analysis

ENUMERATING NEAR-MINIMUM CUTS IN A NETWORK

Matthew J. Gibbons-Lieutenant, United States Navy

B.S., Saint Thomas University, 1986

Master of Science in Operations Research-June 2000

Advisor: R. Kevin Wood, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

We describe an algorithm for enumerating near-minimum-capacity cuts in weighted or unweighted, directed or undirected networks with applications to network interdiction. The algorithm begins by finding a minimum (capacity) cut and then recursively considers potential solutions that include or exclude arcs in that cut. Feasibility is evaluated by solving incremental maximum flow problems at each node of the enumeration tree. Backtracking occurs when the maximum flow, i.e., minimum cut capacity, exceeds a user-specified threshold or inconsistencies are discovered with respect to the included and/or excluded arcs. The algorithm is programmed in Java (JDK 1.2.2) and run on a 500 MHz Pentium personal computer with 96 megabytes of memory. As an example of computational performance, all 6 minimum cardinality cuts are enumerated in .06 seconds for a grid network with 51 nodes and 140 arcs while solving 44 incremental maximum flow problems. All 66 cuts of minimum cardinality, or minimum cardinality plus one, are enumerated in 900 seconds for the same network while solving 653,222 incremental maximum flow problems.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Other (Network Interdiction)

KEYWORDS: Network Interdiction

FITTING FIREPOWER SCORE MODELS TO THE BATTLE OF KURSK DATA

Ramazan Gozel-First Lieutenant, Turkish Army

B.S., Turkish Army Academy, 1994

Master of Science in Modeling, Virtual Environments, and Simulation-September 2000

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: LTC Jeffrey Appleget, USA, TRADOC Analysis Command-Monterey

This thesis applies several Firepower Score attrition algorithms to real data. These algorithms are used in highly aggregated combat models to predict attrition and movement rates. The quality of the available historical data for validation of attrition models is poor. Most accessible battle data contain only starting sizes and casualties, sometimes only for one side. A detailed database of the Battle of Kursk of World War II, the largest tank battle in history, has recently been developed by Dupuy Institute (TDI). The data is two-sided, time phased (daily), highly detailed, and covers 15 days of the campaign. According to combat engagement intensity, three different data sets are extracted from the Battle of Kursk data. RAND's Situational Force Scoring, Dupuy's QJM and the ATLAS ground attrition algorithms are applied to these data sets. Fitted versus actual personnel and weapon losses are analyzed for the different approaches and data sets. None of the models fits better in all cases. In all of the models and for both sides, the Fighting Combat Unit Data set gives the best fit. All the models tend to overestimate battle casualties, particularly for the Germans.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Combat Modeling, Simulation, Attrition, Validation, Firepower Scores, Battle of Kursk

MINIMIZING TIME AWAITING TRAINING FOR GRADUATES OF THE BASIC SCHOOL

Joseph M. Grant-Major, United States Marine Corps

B.S., Ohio State University, 1988

Master of Science in Management-March 2000

Advisors: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

Julie Filizetti, Department of Systems Management

Graduates of The Basic School often spend longer than necessary waiting for their military occupational schools to start. Excessive waiting by graduates is the result of a scheduling conflict between Basic School graduation dates and the start dates of twenty one different schools. This classic scheduling problem results in less available manning for the operational forces. The goal of this thesis is to provide a desktop computer model, based on a linear program, that optimally distributes military occupational specialty quotas to all fiscal year Basic School companies and minimizes the time spent waiting by officers between graduation and the start of their occupational school; while also providing maximum equity of opportunity for all officers to seek any of the twenty one military occupational specialties. The Minimizing Time Awaiting Training model built in this thesis optimally allocates the annual quotas in an efficient and equitable manner using a Pentium II desktop computer in approximately ten seconds. Numerous model runs yielded a total time savings ranging from a high of forty-five work-years, to a low of twenty work-years.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Manpower, Linear Program, Military Occupational Specialties, Modeling, Time Awaiting Training

THESIS ABSTRACTS

IMPROVING NOMINAL RELIABILITY CONFIDENCE BOUNDS USING COVERAGE PROBABILITIES GENERATED THROUGH MONTE CARLO SIMULATION AND ILLUSTRATED BY MONTE CARLO SIMULATION

Jon L. Halverson-Captain, United States Marine Corps

B.S., United States Naval Academy, 1993

Master of Science in Operations Research-September 2000

Advisor: LTC David H. Olwell, USA, Department of Operations Research

Second Reader: Robert R. Read, Department of Operations Research

Estimating the failure time of a product with a high degree of confidence is a difficult endeavor. Clearly, if the product is inexpensive and fails quickly, extensive tests can be run to make prediction more accurate. When the item under scrutiny is expensive, not prone to failure, or both, calculating accurate estimates and confidence bounds becomes more difficult. Furthermore, many methods currently in use are prone to error, sometimes making a critical part appear more reliable than it actually is. Much of our military uses end-items that fall into this category. The lives of our soldiers, sailors, airmen, and Marines often depend on accurate reliability estimates for the equipment and weapons they work on every day.

This thesis first introduces reliability and the common techniques for measuring it. Secondly, it shows that these estimates are often biased. Next, this bias is quantified using Monte Carlo simulation and corrected through simple tables and equations. The tables and equations can be used to map nominal confidence bounds to actual confidence bounds. Lastly, these results are applied to a Marine Corps program and a test run at a major automotive brake system manufacturer. These examples will illustrate the impact of uncorrected bias and what can be done to correct it.

DoD KEY TECHNOLOGY AREA: Materials, Processes, and Structures

KEYWORDS: Reliability, MLE, Rank Regression, Confidence Bounds, B1, Coverage Probabilities, Monte Carlo Simulation, Weibull

AN EVALUATION OF THE AVIATION MAINTENANCE CLIMATE ASSESSMENT SURVEY (MCAS) APPLIED TO THE 3RD MARINE AIR WING

Christopher A. Harris-Lieutenant, United States Navy

B.A., University of New Mexico, 1988

Master of Science in Operations Research-June 2000

Advisor: CDR John K. Schmidt, USN, School of Aviation Safety

Second Reader: Lyn R. Whitaker, Department of Operations Research

Faced with aging aircraft and fewer acquisitions, Naval Aviation has redoubled its effort to preserve assets through preventive maintenance and reduction of aircraft mishaps. Eighty percent of all mishaps are due in part to human error, and approximately one out of five major mishaps are due to maintainer, line, or facility related factors. Among various efforts to systematically reduce mishaps is the use of the Maintenance Climate Assessment Survey (MCAS). This survey is designed to capture maintainer perceptions of safety. This thesis analyzes the results of 977 responses to MCAS given to the 3rd Marine Air Wing (MAW) maintenance personnel. In addition, it explores the MCAS's relationship with human errors present in 21 maintenance-related incidents (MRIs) using the Human Factors Analysis and Classification System - Maintenance Extension. This analysis finds statistically different responses among the squadrons of the 3rd MAW to the MCAS. These differences show the MCAS can detect variations between aviation units and associated Model of Organization Safety Effectiveness components. While no significant correlation between the nine adequately surveyed squadrons and their MRIs is found, a content analysis of the MCAS shows there is a relationship between the MRIs a squadron experiences and the items of the six MOSE components.

DoD KEY TECHNOLOGY AREAS: Human Systems Interface, Manpower, Personnel, and Training

KEYWORDS: Safety Climate, Maintenance, Human Factors, Human Error, High Reliability Organizations, Safety Culture, Naval Aviation

THESIS ABSTRACTS

FLEET SUPPORT OFFICER FLEET TRAINING (FSOFT): SHOULD A SEA TOUR BE A REQUIREMENT?

Rhonda M. Henderson-Lieutenant, United States Navy

B.B.A., George Washington University, 1993

Master of Science in Systems Management-June 2000

Advisors: Julie Filizetti, Department of Systems Management

George W. Conner, Department of Operations Research

This thesis proposes a Fleet Support Officer Fleet Training (FSOFT) program that would allow Fleet Support Officers (FSOs) to attend Surface Warfare Officer School in Newport, RI, be assigned a Surface Warfare Officer (SWO) division officer tour, as an initial assignment, and then obtain a warfare pin. Following the SWO division officer tour, the FSO would resume a career in the FSO community. The feasibility of such a program and the impacts on both the SWO and FSO communities are discussed. This program would provide FSOs with the necessary background and training to make them better support officers, more fully preparing them for their careers in the Navy. It would provide FSOs with fleet experience that would give them a greater appreciation of the Navy's mission. It would also give them a better understanding of the support required of the Fleet in the FSO core competencies of Space and Electronic Warfare (SEW), Manpower Systems Analysis (MSA), and Logistics. The program would also give FSOs the essential skills in standing watches and managing administrative duties of a division officer, and would better prepare them to fill lieutenant commander (LCDR) and above, at-sea billets in the FSO community.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Other (Fleet Support Officer)

KEYWORDS: Fleet Support Officer Community, Fleet Support Officer Training, Fleet Support Officer Fleet Training (FSOFT)

HUMAN FACTORS ANALYSIS OF U.S. NAVY AFLOAT HAZARDOUS MATERIAL MISHAPS

Matthew W. Hildebrandt-Lieutenant, United States Navy

B.A., Jamestown College, 1983

Master of Science in Operations Research-June 2000

Advisor: CDR John K. Schmidt, USN, School of Aviation Safety

Second Reader: Lyn R. Whitaker, Department of Operations Research

Personnel aboard U.S. Naval vessels face risk of occupational injury and illness. A substantial part of that risk involves incidents, or cases of exposure to hazardous materials (HAZMAT). Due to the nature of this type of risk, there are many opportunities to improve safety and readiness and to reduce the number of workdays lost to injury. For the period from CY94 – CY98 there were 627 HAZMAT mishaps involving 820 personnel onboard U. S. Navy surface ships. HAZMAT root causal factors were identified through the evaluation of Special Case Mishap Reports maintained by the Naval Safety Center; 89% of these mishaps were attributable to human error. Failure to use personal protective equipment (30.0%) and failure to recognize a hazardous situation (24.6%) were the primary reasons given for the mishaps. Comparisons were made between HAZMAT, electrical shock and back injury mishaps. While minor differences exist between these types of mishaps, overall there were many commonalities that may be observed. Most are relatively minor as classified by severity, occur aboard Carriers, and involve personnel in the E-3 to E-5 rank range.

DoD KEY TECHNOLOGY AREAS: Biomedical, Human Systems Interface, Manpower, Personnel, and Training

KEYWORDS: Maritime Mishaps, Hazardous Material, Accident Analysis, Human Factors, Human Error, Poisson Process

THESIS ABSTRACTS

A HEURISTIC FOR LAND-ATTACK PREDESIGNATION

Bertram C. Hodge-Lieutenant, United States Navy

B.S.A.E., Purdue University, 1993

Master of Science in Operations Research-December 1999

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

Predestination is the assignment of land-attack missiles on surface ships and submarines to target aim points. The assignment process has two stages: (1) the allocation of land-attack missiles to launch platforms, considering all tasks and platforms simultaneously; and (2) given this preliminary allocation, the refined assignment of land-attack missiles to tasks aboard an individual platform, separately considering each platform and the associated allocations obtained from (1). This thesis addresses only the *first stage*, i.e., the automated allocation of land-attack missiles to surface ships. Currently, strike planners possess no tools that yield consistent and reproducible assignments. Two previous NPS models address the allocation of tasks to launch platforms. One does not address details such as multiple launch areas or multiple time periods, and the other proposes a model that is too computationally expensive to implement in an operational setting. In this thesis, a tool is developed to yield allocations similar to those obtained with the latter model in a much shorter amount of time.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Conventional Weapons

KEYWORDS: Tomahawk Land-Attack Missile, Heuristic, Weapons Allocation

OPTIMIZATION OF PROCUREMENT SCHEDULING FOR MAJOR DEFENSE ACQUISITION PROGRAMS

Donald E. Humpert-Major, United States Marine Corps

B.A., University of Colorado, 1987

M.A., University of Redlands, 1994

Master of Science in Operations Research-September 2000

Advisor: Alan R. Washburn, Department of Operations Research

Second Reader: CDR Timothy P. Anderson, USN, Department of Operations Research

As the Defense Acquisition Executive (DAE), the Under Secretary of Defense for Acquisitions, Technology and Logistics has full responsibility for supervising the performance of the DoD Acquisition System. A challenge to the DAE is in determining the most efficient allocation of funding in procuring of over eighty Major Defense Acquisition Programs. This thesis develops six different cost functions based on the Unit Theory learning curve model for estimating the cost of each of these MDAP systems. The most suitable of these adds an annual overhead component to the cost modeled by the learning effect. This function is implemented in an integer-linear optimization model, the Procurement Scheduling Optimization Model (PSOM). PSOM allows the planner to specify: an annual budget limit; demand quantities for each system for all years in the planning horizon; minimum and maximum annual production rates; earliest and latest full rate production (FRP) start periods; and low rate initial production (LRIP) costs and quantities. PSOM determines the minimum cost procurement schedule given these constraints, finding the optimal quantity of each system to be procured each year of the planning horizon. This thesis models the cost of seventeen of the MDAP systems and optimally schedules them over an eighteen year planning horizon. PSOM can easily be expanded to include all eighty-plus MDAP systems. PSOM is a tool available to the acquisition planners and decisionmakers to assist in optimally allocating procurement funding.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Acquisition, Procurement, Cost Estimation, Learning Curve, MDAP, Optimization, Linear Program, Integer-Linear Program

THESIS ABSTRACTS

SENSITIVITY ANALYSIS OF THE TOPOLOGY OF CLASSIFICATION TREES

Izumi Kobayashi-Technical Official 2nd Grade, Japan Defense Agency

M.S., Ochanomizu University, 1992

Master of Science in Operations Research-December 1999

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: Robert A. Koyak, Department of Operations Research

The use of classification trees is one of the most widely used techniques in classification. It is well known that classification trees are not stable in their topology, in contrast to their robustness with respect to misclassification rate.

This thesis defines a measure that compares the topology of two trees and studies how a tree's topology changes when the dependent (Y) variable or the independent (X) variables are perturbed. This allows us to examine the "robustness" of tree topology under perturbation and to compare it to the robustness with respect to the misclassification rate under the same perturbations.

We show that the tree topology can change significantly even for small perturbations in many sets of data. This suggests that even small measurement errors in the variables can affect the tree topology greatly. Because data are often measured with error, it follows that splitting rules in trees may not be suitable for use in making policy decisions. We propose a measure for tree topology, and show that tree topology changes faster than the misclassification rate does under mild perturbations. This finding formalizes the concept that tree models are more stable in terms of misclassification rate than in terms of topology.

DoD KEY TECHNOLOGY AREA: Other (Statistics)

KEYWORDS: Classification Tree, Sensitivity Analysis

ADVANCED NAVAL SURFACE FIRE SUPPORT WEAPON EMPLOYMENT AGAINST MOBILE TARGETS

Hung B. Le-Lieutenant, United States Navy

B.S., United States Naval Academy, 1992

Master of Science in Operations Research-December 1999

Advisor: Arnold H. Buss, Department of Operations Research

Second Reader: LCDR Douglas J. MacKinnon, USN, Department of Operations Research

Key threat trends have identified shortfalls in Naval Surface Fire Support (NSFS), a mission area that is undergoing rapid evolution. The Navy's ability to effectively provide sea-based fire support to ground forces is profoundly challenged by mobile and reduced dwell time targets. Furthermore, longer range enemy weapon systems, which must be destroyed at greater ranges prior to their engagement of friendly forces, will make NSFS timeliness a difficult proposition. To overcome these threat trends, the United States is developing sophisticated weapons that promise increased lethality, greater ranges and improved responsiveness. However, the development of robust firing policies to ensure effective weapon utilization has lagged behind the hardware. Existing computer models and simulations have not addressed the question of NSFS gun/missile firing policy. This thesis develops the Naval Surface Fire Support Simulation (NSFSSim) model, a discrete-event simulation that serves as an analysis tool to determine favorable firing policies for future NSFS gun and missile systems in support of determining the appropriate NSFS weapons mix. NSFSSim models ships and their associated NSFS weapons in counterbattery and call fire missions against mobile, reduced dwell time targets. Exploratory analysis using NSFSSim yields useful insights, and the component-based architecture underlying the model provides significant flexibility for further analysis.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Conventional Weapons, Modeling and Simulation

KEYWORDS: Discrete-Event Simulation, Firing Policy, Java, Modeling and Simulation, Naval Surface Fire Support

THESIS ABSTRACTS

PLANNING FLIGHT TRAINING FOR THE TRANSITION TO THE V-22 OSPREY

Robert M. Liebe-Major, United States Marine Corps

B.S., United States Naval Academy, 1990

Master of Science in Operations Research-September 2000

Advisor: Gerald G. Brown, Department of Operations Research

Second Reader: Robert F. Dell, Department of Operations Research

The Department of Defense is fielding the V-22 Osprey tilt-rotor aircraft in the Marine Corps and Air Force. Marine Medium Tilt-Rotor Training Squadron 204 (VMMT-204) in Jacksonville, North Carolina, is the sole Fleet Replacement Squadron (FRS) for initial V-22 training, and planners must develop pilot training schedules that support service goals without exceeding VMMT-204 resources. Currently, planners manually create FRS training schedules with monthly fidelity, guided by past analysis and personal experience. However, manual methods are cumbersome and provide few measures of resource utilization. Marine planners need a decision support tool to automate V-22 FRS scheduling, given transition guidance. This thesis introduces an optimization model that takes as input Marine Corps operational requirements, Air Force and Marine annual training goals, FRS training syllabus requirements and resources available, and a prioritization scheme to resolve conflicts between competing goals. The output is a schedule of training classes identified by unit, FRS syllabus and follow-on training, and class convening date (with half-month fidelity) over a ten-year planning horizon. The model uses Microsoft Excel to input data and automate output reports for training goals, resource utilization, and training possibilities with unscheduled resources. A ten-year training plan can be completed in about 10 minutes.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Air Vehicles, Modeling and Simulation, Computing and Software, Conventional Weapons

KEYWORDS: Decision Support, Manpower Planning, Linear Programming, V-22 Osprey, Flight Training

DETERMINISTIC AND STOCHASTIC MODELS OF BIOLOGICAL ATTACKS ON SEAPORTS OF DEBARKATION DURING A MAJOR THEATER WAR

Long Piao Loh-Major, Republic of Singapore Navy

B.A., Nanyang Technological University, 1992

Master of Science in Operations Research-September 2000

Advisors: R. Kevin Wood, Department of Operations Research

Javier Salmerón, Department of Operations Research

Second Reader: Robert F. Dell, Department of Operations Research

Alexander [1999] develops deterministic and stochastic optimization models to study how a biological weapons attack upon a Seaport of Debarkation (SPOD) during a Major Theater War (MTW) can disrupt the force build-up required to support that war. Force disruption is measured by lateness of cargo and non-deliveries. The current research improves the realism of those models: Ships may now be re-routed away from an SPOD that has just been attacked (to an alternate SPOD with spare cargo-handling capacity), and cargo cannot be unloaded until decontamination is complete. The improved models are tested using unclassified data that simulates requirements for an MTW in the Persian Gulf. Results indicate that re-routing of ships is beneficial if the re-routing delay, measured by the time to travel to the alternate SPOD, is less than the time required to decontaminate the attacked SPOD. Uncertainty in the timing of the biological attack is handled by the stochastic model, which minimizes the sum of expected disruption over several possible attack scenarios. Results show that limited intelligence about a potential attack can mitigate the disruption that attack might cause.

DoD KEY TECHNOLOGY AREAS: Chemical and Biological Defense, Modeling and Simulation

KEYWORDS: Optimization, Stochastic Optimization, Biological Warfare

THESIS ABSTRACTS

GRAPHIC USER INTERFACE DESIGN FOR MAPPING, INFORMATION, DISPLAY, AND ANALYSIS SYSTEMS

**James P. Lowell-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993**

Master of Science in Operations Research-June 2000

Advisors: William K. Krebs, Department of Operations Research

Gordon H. Bradley, Department of Operations Research

Second Reader: Rudolph P. Darken, Department of Computer Science

This thesis evaluates both the interface design process and the map-based mission planning tools of the Loosely Coupled Components Research Group, Naval Postgraduate School for human factors usability. After identifying flaws in the process and usability problems in the interface designs, a new software design process and map-based mission-planning tool are developed. A usability study was conducted on the new mission-planning tool, determining it to be a usable product while establishing baseline data for future interface improvements. The map-based mission-planning tool, written in the Java programming language, is called the Mapping, Information, Display, and Analysis System (MIDAS). In its Beta form, MIDAS can display any geo-referenced map or image and allow users to annotate it with several graphical tools. Future versions will incorporate existing map-based decision-aiding tools such as optimal track routing, intelligence image rubber-sheeting, and wirelessly networked unit tracking. This thesis recommends the incorporation of human factors early in the software design process and quality usability studies on interfaces to ensure a usable product.

DoD KEY TECHNOLOGY AREAS: Battle Space Environments, Command, Control, and Communications, Computing and Software, Human Systems Interface

KEYWORDS: Joint Vision 2010, Information Superiority, Battlespace Dominance, Java, Map, Mission Planning, Land Warrior, Command Post of the Future, Graphic User Interface, Human Computer Interaction, Usability Study, Loosely Coupled Components

THORN: A STUDY IN DESIGNING A USABLE INTERFACE FOR A GEO-REFERENCED DISCRETE EVENT SIMULATION

**Patrick V. Mack-Lieutenant, United States Navy
B.S., Oregon State University, 1992**

Master of Science in Computer Science-September 2000

Master of Science in Operations Research-September 2000

Advisor: Arnold H. Buss, Department of Operations Research

Second Reader: Rudolph P. Darken, Department of Computer Science

This thesis evaluates the usability of THORN, a system for displaying a discrete event simulation model in a geographic information system. THORN was developed to enhance the planning phase of Operational Maneuver from the Sea. The goals of this study were to test the system against usability criteria and provide a benchmark for future testing. The purpose of this analysis was to (1) create a system for viewing discrete event simulations fused with geo-referenced spatial information, (2) determine the system's usability, (3) identify problem areas in the graphical user interface, and (4) provide a proof of concept for incorporating usability in the design of military planning tools. The study's scenario is based on the principles outlined in the white paper Operational Maneuver from the Sea. The study tested whether THORN met the usability objectives of (a) 90% successful tasks completion, (b) ease-of-use ratings of "somewhat easy" or better, and (c) satisfaction ratings of "somewhat satisfied" or better. THORN met all of these usability objectives.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Computing and Software, Modeling and Simulation

KEYWORDS: Operational Maneuver from the Sea, GIS, Simulation, Software Components

THESIS ABSTRACTS

THE POTENTIAL IMPACT OF HYPERSPECTRAL IMAGERY ON AMPHIBIOUS WARFARE PLANNING

Keith W. Maly-Lieutenant, United States Navy
B.S., Rochester Institute of Technology, 1994

Master of Science in Systems Technology-December 1999

Advisors: William K. Krebs, Department of Operations Research

Richard C. Olsen, Department of Physics

Military image analysts primarily use panchromatic and radar images to aid situational awareness in preparing a mission plan. Although analysts rely on these two formats, there are situations where these two sensors are unable to detect potential threats, i.e., buried mines. The Department of Defense has proposed using a hyperspectral sensor to detect threats that otherwise may not be detected by existing sensors. In order to determine the utility of hyperspectral imagery for mission planning, a task analysis was conducted at two Joint Intelligence Centers to measure image analysts' preferences to infrared, radar, panchromatic, and hyperspectral imagery during an amphibious planning process. The results showed that the image analysts were most confident using panchromatic imagery for the majority of the planning tasks; however, the analysts exhibited uncertainty for other tasks, such as detecting buried mines. Further analysis showed that image analysts could reduce their uncertainty in detecting buried mines and producing bathymetric maps by using hyperspectral imagery. Although hyperspectral imagery reduced uncertainty during mission planning, operators report that this imagery is confusing. To integrate hyperspectral imagery in mission planning, image analysts must be trained to interpret a hyperspectral scene and understand how to exploit its' spectral characteristics.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Sensors, Visual Information Processing, Hyperspectral Imagery, Spectral Imagery, Image Interpretation, Amphibious Planning

AN EVALUATION OF THE HYDRA-7 COUNTERMINE WEAPON SYSTEM

Tim A. Maxwell-Major, United States Marine Corps
B.S., Texas A&M University, 1988

Master of Science in Operations Research-June 2000

Advisor: James N. Eagle, Department of Operations Research

Second Reader: William G. Kemple, Command, Control, Communications, Computers, and Intelligence Academic Group

The basic principle of Maneuver Warfare in the 21st century is the seamless integration of sea and land as maneuver space. Unfortunately, our inability to conduct counter-mine and counter-obstacle operations in the littorals severely curtails our ability to conduct Amphibious Warfare, a key ingredient to maneuver. Hydra-7, a possible solution to this problem, is one of the most promising counter-mine weapons under development, but its final performance level will depend on the effectiveness of sub-component technologies. These sub-component technologies have yet to reach maturity and may not perform as well as desired. This thesis provides analysis procedures and models to predict Hydra-7 effectiveness for a broad range of possible performance values of sub-component systems. The methodology will determine which of the sub-component technologies is most critical to the final performance of Hydra-7.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Simulation, Parameterization, Sensitivity Analysis

THESIS ABSTRACTS

AN EXPLORATORY ANALYSIS OF THE MILITARY VALUE OF INFORMATION AND FORCE

**John McGunnigle, Jr.-Lieutenant, United States Navy
B.S., United States Naval Academy, 1992**

Master of Science in Operations Research-December 1999

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: Wayne P. Hughes, Department of Operations Research

This thesis addresses the military value of information in conflict. It is composed of three complimentary experiments. The first experiment uses a simple contest to assess how military decision makers perceive and use information. The results of the experiment demonstrate that military decision makers do not always use information optimally. Equally insightful, military decision makers significantly overestimate the value of information compared to force advantage. The second experiment is an exploratory analysis of like naval surface forces and explores the value of information versus force advantage in modern naval surface combat using a computational model of naval missile combat. The results of the exploratory analysis of like naval forces suggest that increasing information advantage can enhance but occasionally may degrade a force's effectiveness. In contrast, increasing force advantage in the same conflict always enhances the combat effectiveness of the forces investigated. The third experiment analyzes a more realistic asymmetric scenario. In this case study, American aegis-type ships engage more numerous coastal defense-type forces. The results show the advantage of numbers even when the aegis-type ships have virtually total information.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Information, Simulation, Naval Combat

RANGER AIR LOAD PLANNER

Maximo A. Moore, III-Captain, United States Army

Master of Science in Operations Research-June 2000

B.S., State University of New York College at New Paltz, 1992

Advisor: Gordon H. Bradley, Department of Operations Research

Second Reader: Gerald G. Brown, Department of Operations Research

The United States Army 75th Ranger Regiment conducts combat parachute operations as part of United States Special Operations Command (USSOCOM). The Rangers are the largest deployable asset of USSOCOM, and are required to plan and execute large-scale parachute assaults into hostile theaters with little or no notice. Generally fighting numerically superior enemy, far from the support of the conventional Army, Rangers must arrive capable of self-sustaining combat operations in any operational environment. This thesis provides Ranger air load planners a tool to rapidly plan feasible mission equipment loads. The Ranger Air Load Planner (RAP) is simple to learn and operate, provides load plans selected from pre-approved, United States Air Force load templates, and supports dynamic decision support with rapid solution response. An optimization model is used in the thesis to objectively assess the quality of RAP load plans. RAP is a working product that can be adapted for use in air load mission planning by all units under USSOCOM.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Mission Planning, Analysis, Special Operations, MPARE, Java, Loosely Coupled Components

THESIS ABSTRACTS

EXPLORATORY MODEL ANALYSIS OF THE SPACE BASED INFRARED SYSTEM (SBIRS) LOW GLOBAL SCHEDULER PROBLEM

**Brian L. Morgan-Lieutenant Commander, United States Navy
B.S., University of Virginia, 1989**

Master of Science in Operations Research-December 1999

Advisor: Thomas W. Lucas, Department of Operations Research

Second Readers: Robert R. Read, Department of Operations Research

Thomas D. Gottschalk, California Institute of Technology

Proliferation of theater ballistic missile technologies to potential U.S. adversaries necessitates that the U.S. employ a defensive system to counter this threat. The system that is being developed is called the Space-Based Infrared System (SBIRS) "System of Systems." The SBIRS Low component of the SBIRS "System of Systems" will track strategic and theater ballistic missiles from launch to reentry and relay necessary cueing data to missile interceptors before the missiles reach friendly forces or countries whose safety is a vital interest to the U.S. SBIRS Low has a number of critical system requirements that for any given satellite are mutually exclusive for the length of time needed to complete the specified tasking. This limitation implies a system capacity on the total number of ballistic objects the SBIRS Low system can track at any given time. Applying exploratory model analysis, the SBIRS Low model uses the Monte Carlo method to explore large regions of the model space to identify key factors in the system and to provide insight into different tasking schemes for individual satellites. The exploratory model analysis, which consisted of 13,760,000 missiles being tracked in the analysis of the CSS-2 and M-9 missiles, yielded the following significant results: (a) defining the "best" satellite is nontrivial, (b) the SBIRS Low system was unable to initiate a booster track for an unacceptably large percentage of M-9 missiles launched near the equator, (c) if the system anticipates a long delay in revisiting a track, a stereo view should be scheduled immediately prior to the start of the delay, (d) mono viewing alone does not provide the required track accuracy, (e) track accuracy is a function of missile classification, and (f) the instantaneous track accuracy versus sensor revisit rate does not fit any well-known probability distribution.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Ballistic Missile Defense, Exploratory Model Analysis, Space-Based Infrared Systems

CALCULATION OF BARRIER SEARCH PROBABILITY OF DETECTION FOR ARBITRARY SEARCH TRACKS

**Wyatt J. Nash-Lieutenant, United States Navy
B.S., University of New Mexico, 1993**

Master of Science in Operations Research-March 2000

Advisor: James N. Eagle, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

The Surface Warfare Development Group is responsible for conducting the Ship Anti-Submarine Warfare Readiness/Effectiveness Measuring Program. They currently employ a standard set of measures for evaluating the performance of shipboard anti-submarine warfare sensors. This research investigates several new performance-based measures to determine if they are more suitable than the standard measures for evaluating the conduct of anti-submarine warfare barrier searches. The investigation simulates barrier searches to determine probability of detection, calculates the proposed measures, and compares the two. The results indicate that the proposed measures can be improved. A barrier search algorithm exploiting target-relative space ideas is developed which generalizes the classical search theory results for predicting probability of detection during barrier search.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Surface Warfare Development Group (SWDG), Shipboard Anti-Submarine Warfare Readiness/Effectiveness Measuring Program (SHAREM), Barrier Search, Modeling and Simulation, Java

THESIS ABSTRACTS

A COMPARISON OF OUTPUT FROM THE LOS ALAMOS NATIONAL LABORATORY (LANL) PARALLEL OCEAN PROGRAM (POP) MODEL WITH SURFACE VELOCITY DATA FROM DRIFTING BUOYS IN THE NORTH ATLANTIC OCEAN

Jimmy W. Pelton-Lieutenant, United States Navy

B.S., North Carolina State University, 1993

Master of Science in Operations Research-March 2000

Advisors: Julie L. McClean, Department of Oceanography

Pierre-Marie Poulain, Department of Oceanography

Second Reader: Lyn R. Whitaker, Department of Operations Research

Surface velocity fields from two configurations of the Los Alamos National Laboratory (LANL) Parallel Ocean Program (POP) model are compared to surface velocity data from satellite-tracked buoys in the North Atlantic. Separate analyses are conducted for each model configuration. In the first analysis, output from a 1/6-degree, 20-level model version is compared with five years (1993-1997) of drifter data, based on both Eulerian and Lagrangian statistics. In the second analysis, newly-available output from a 1/10-degree, 40 level version is compared to a two-year subset (1993-1994) of the data, and to 1/6-degree output over the same time frame. The latter comparison is based on Eulerian statistics alone.

The five-year comparison shows that the 1/6-degree model produces inaccuracies in some features, and generally underestimates velocity variance. Modeled Lagrangian time scales are too long, while the length scales are too short. The two-year comparison shows that at the higher vertical and horizontal resolution of the 1/10-degree model, there is a striking improvement in the spatial distribution of energy and resolution of the variance field.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Battlespace Environments

KEYWORDS: Numerical Modeling, Ocean Forecasting, Model Evaluations

OPTIMIZING PROCUREMENT OF SPECIAL OPERATIONS WEAPONS AND EQUIPMENT

Michael A. Pfarrer-Lieutenant, United States Navy

B.S., Ohio State University, 1994

Master of Science in Operations Research-June 2000

Advisor: Gerald G. Brown, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

The Joint Operational Stock (JOS) is a centrally-located inventory of Special-Operations peculiar weapons and equipment, managed by the United States Special Operations Command (USSOCOM). New procurement of JOS weapons and equipment is currently planned by manually prioritizing the item-wise shortfalls experienced in the JOS inventory during the previous year. This method has not always provided convincing justification for funding, as indicated by the loss of such funding in fiscal year 1999. Also, new technology and other items not historically demanded must be handled in an ad-hoc fashion. We introduce a procurement planning tool that seeks to maximize the ability to completely loadout special operations missions by coordinating year-by-year procurement of individual items. Rather than focus just on history, concentration is on supporting future missions over an entire multi-year planning horizon. The plans are quickly suggested by a simple greedy myopic heuristic shown to produce almost-optimal advice.

DoD KEY TECHNOLOGY AREA: Other (Weapons and Equipment Procurement)

KEYWORDS: Logistics, Special Operations Forces, Joint Operational Stock, Optimization, Heuristic, Inventory, U.S. Special Operations Command

THESIS ABSTRACTS

DETERMINANTS OF FLIGHT TRAINING PERFORMANCE: AN ANALYSIS OF THE IMPACT OF UNDERGRADUATE ACADEMIC BACKGROUND

**Paul M. Reis-Lieutenant, United States Navy
B.S., University of Florida, 1993**

Master of Science in Operations Research-June 2000

Advisor: Samuel E. Buttrey, Department of Operations Research

Second Reader: William K. Krebs, Department of Operations Research

This thesis uses pre-commissioning academic and demographic factors, along with flight school performance data to measure pilot success in flight school. The goal is to determine if undergraduate major or school attended affect flight school performance. Measures of effectiveness include: (1) Flight School Completion Status, (2) Aviation Pre-Flight Indoctrination Composite Scores, and (3) Primary Flight Training Composite Scores. Recruitment for naval aviators is focused on individuals with "technical majors," according to present policy of the Naval Recruiting Command. This recruiting philosophy is based on the "Rickover Hypothesis," which postulates that naval officers with technical degrees are superior to naval officers with non-technical degrees. The Logit model showed that aviators with engineering degrees have a statistically greater chance of completing flight school than aviators with non-engineering technical or non-technical degrees. In addition, the results showed an association between academic background and flight school performance. This research justifies the current Navy policy of concentrating aviator recruitment efforts on individuals with technical degrees.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Aviator Selection, Aviation Flight Training, Classification and Regression Trees, CART, Cross-Validation, Tree, Logistic Regression, Logit

STATISTICAL ANALYSIS OF THE NAVAL INVENTORY CONTROL POINT REPAIR TURN-AROUND TIME FORECAST MODEL

**Michael J. Ropiak-Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1987**

Master of Science in Operations Research-June 2000

Advisor: Robert A. Koyak, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

Accurate forecasting of repair turn-around time (RTAT) of United States Navy depot level repairable items is critical to achieving optimal service levels while minimizing procurement and repair costs. The Navy's Inventory Control Point has developed a forecast model that uses sophisticated Statistical Process Control techniques and non-parametric algorithms to forecast RTAT. This thesis attempts to validate the Navy's RTAT forecast model by comparing its performance to those of simple time series forecasting methods. It was found that the assumptions implicit in the UICP RTAT forecast model have a significant impact on forecast accuracy. In addition to documenting these model properties, a goal of this thesis is to identify variables that the UICP model does not use in RTAT forecasting which may improve its accuracy. The research focuses on data for repairable items that have high dollar value and the greatest number of repair transactions per quarter.

Results show that the Navy's model is not consistently more accurate than any of the alternative techniques examined, and that it tends to ignore many large RTAT observations, causing it to under-forecast RTAT. Thesis research also reveals that accounting for differences in disparate designated overhaul points may significantly improve the prediction of RTAT. Finally it is shown that additional variables, derived from a NAVICP Philadelphia database and designed to capture the queueing aspect of the repair process, may significantly improve the prediction of RTAT. These findings point to the use of queueing information to obtain more accurate RTAT forecasts.

DoD KEY TECHNOLOGY AREA: Other (Inventory, Forecasting)

KEYWORDS: Forecasting, Statistics, Repairable, Inventory, Operations Research

THESIS ABSTRACTS

MODELING AND SIMULATION SUPPORT FOR THE OPERATIONAL TEST AND EVALUATION OF A TACTICAL AIRBORNE RECONNAISSANCE SYSTEM

**Kevin J. Schmidt-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993**

Master of Science in Operations Research-December 1999

Advisors: Donald P. Gaver, Department of Operations Research

Patricia A. Jacobs, Department of Operations Research

Second Reader: Arnold H. Buss, Department of Operations Research

Today's decreasing defense budget has forced the military to reduce its spending on operational testing of new equipment, among many other areas. Reduced testing has forced evaluators to focus their attention on possible sensitive issues prior to and during testing of new equipment. The Simulation, Test, and Evaluation Process implemented in 1995 to help reduce testing costs has been an integral part of the test and evaluation process.

This thesis develops a stochastic simulation to determine the sensitive aspects of operating and maintaining a mobile reconnaissance platform, specifically a helicopter, prior to and during actual testing. The simulation can also be implemented to compare the effectiveness of different mobile reconnaissance platforms instead of conducting side-by-side testing of actual platforms.

This simple, stochastic, event-driven simulation may be used to conduct sensitivity analysis on system design and operational issues, including attrition, for mobile reconnaissance platforms in order to focus the attention of the testers and evaluators on sensitive issues during testing.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Modeling and Simulation

KEYWORDS: Modeling and Simulation, Maintenance and Repair, Mobile Reconnaissance Platform, Attrition, Non-homogeneous Poisson Process, Operational Test and Evaluation, Java, Simkit

PREDICTING CASUALTIES IN SIMULATION MODELS ("COSAGE") USING DISCRETE-TIME ANALYTICAL MODELS

**Marc C. Schweighofer-Lieutenant, United States Navy
B.S. United States Naval Academy, 1991**

Master of Science in Operations Research-December 1999

Advisors: Donald P. Gaver, Department of Operations Research

Patricia A. Jacobs, Department of Operations Research

Second Reader: Alan R. Washburn, Department of Operations Research

The Army's Combat Sample Generator (COSAGE) is a two-sided, symmetrical, high-resolution stochastic simulation model that projects the outcome of ground combat between two forces. Blue force is typically a division; Red force size may be scaled from a fraction of a division to a combined arms army. Because COSAGE is high-resolution (many asset types), it requires extensive data preparation time, and because output is the result of 16-20 replications, substantial simulation run-time.

The analytical model implementation of this thesis is developed to economically project ground combat attrition and munitions expenditures beyond the 48-hour period currently modeled in COSAGE. The implementation evaluates Bayesian estimators of time-period survivorship to estimate expected numbers of kills, both friendly and enemy, during the first 48 hours of combat, then extrapolates those estimates in discrete time steps (here 24 hours) beyond 48 hours. The implementation can be used to project COSAGE output for all combat postures in Northeast and Southwest Asia (NEA and SWA respectively).

An application of the current implementation is to support the warfighting Commanders in Chief (CinC) need to create a Phased Threat Distribution (PTD) in accordance with the Capabilities-Based Munition Requirement Process introduced in June 1997.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Munition, Combat Sample Generator, Phased Threat Distribution, Capabilities-Based Munition Requirement Process

OPTIMAL POSITIONING OF NAVAL PRECISION GUIDED MUNITIONS

Billy K. Sentlinger-Lieutenant Commander, United States Navy

B.A., University of California, Los Angeles, 1985

Master of Science in Operations Research-June 2000

Advisor: David A. Schrady, Department of Operations Research

Second Reader: Siriphong Lawphongpanich, Department of Operations Research

The Department of Defense (DoD) Report to Congress, *Kosovo/Operation Allied Force After-action Report*, listed the pre-positioning of precision guided munitions (PGM) as a leading force sustainment concern. The high utilization of PGMs in recent smaller-scale contingency operations (SSCs) such as *Operation Allied Force* has led DoD to examine the PGM pre-positioning policy. Current doctrine positions PGMs per the possible conflicts detailed in the Defense Planning Guidance (DPG). Currently, the DPG only addresses the two nearly simultaneous major theater wars (MTWs). Although PGM expenditures during SSCs may deplete a significant portion of pre-positioned stocks, they are not considered when planning the pre-positioning of PGMs. Additionally, when PGM stocks are depleted while conducting SSCs, the decrease in overall military readiness may adversely affect the operational commanders' ability to conduct MTWs in their areas of responsibility. The purpose of this thesis is to develop a method to optimally plan the positioning of PGMs for SSCs and the DPG designated MTWs.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Logistics, Ordnance, Optimization

AIM-7 SPARROW MK-58 ROCKET MOTOR RELIABILITY AND LIFE DATA ANALYSIS

Anthony A. Sorell-Lieutenant Commander, United States Navy

B.S., DeVry Institute of Technology, 1986

Master of Science in Operations Research-June 2000

Advisor: LTC David H. Olwell, USA, Department of Operations Research

Second Reader: CDR Matthew G. Boensel, USN, Department of Operations Research

The AIM-7 Sparrow missile is a radar-guided, air-to-air missile that is widely deployed and used by U.S. and NATO (North Atlantic Treaty Organization) forces. Due to recent catastrophic failures of the MK-58 rocket motor, the future of the AIM-7 Sparrow is uncertain as it approaches the end of its predicted service life of twenty years. A large number of AIM-7 Sparrows are currently in the inventory of the United States and NATO.

The catastrophic failure of a MK-58 rocket motor could result in loss of life, loss of aircraft, and/or an unsuccessful mission. This thesis analyzes the existing catastrophic failure data of the AIM-7 Sparrow to develop a reliability model of the MK-58 rocket motor as a function of the motor's age using the Weibull distribution. The model parameters were obtained using both maximum likelihood estimators (MLE) and Bayesian methods.

The model can be used to determine the expected useful life of the MK-58 rocket motor based on risk and mission. The model also assists in providing a timeframe for the development, procurement, and replacement for the AIM-7 Sparrow with another air-to-air missile system.

DoD KEY TECHNOLOGY AREA: Conventional Weapons

KEYWORDS: Reliability, MK-58 Rocket Motor, Air-to-Air Missiles, Sparrow, AIM-7, Bayesian, MLE

THESIS ABSTRACTS

THE FLAMING DATUM PROBLEM WITH VARYING SPEED

Alberto A. Soto-Lieutenant, Chilean Navy

B.S., Chilean Navy Polytechnic Academy, 1991

Master of Science in Operations Research-June 2000

Advisor: Alan R. Washburn, Department of Operations Research

Second Reader: Paul J. Sanchez, Department of Operations Research

The problem of detecting an enemy submarine whose possible position was revealed by the hit of a torpedo is known as the "Flaming Datum" problem. All previous studies devoted to this theme make unrealistic assumptions about the speed of the escaping target when dealing with a diesel-electric submarine. In this kind of submarine the constraint imposed by the remaining charge of its batteries determines that its behavior is essentially conservative in how fast it should escape.

The objective of this thesis is to explore the idea of varying speed in the flaming datum problem. Two different approaches are considered. An analytical model is developed based on the relationship among some of the physical factors that could determine or constrain the behavior of a diesel submarine while escaping from the area of the flaming datum. The second approach considers a discrete event simulation using the Java-based Simkit package. Data analysis is used to determine a possible fit for the simulation results. Several tactics are explored to determine their effects on detection probability.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles, Modeling and Simulation, Other (Search and Detection)

KEYWORDS: Unit Circle, Detection Rate, Edge, Farthest on Circle (FOC), Maximum Possible Distance (MPD)

AN EVENT-STEP SIMULATION FOR EVALUATING DD21 SYSTEM EFFECTIVENESS

William H Snyder, III-Lieutenant, United States Navy

B.S., Norwich University, 1993

Master of Science in Operations Research-September 2000

Advisor: Alan R. Washburn, Department of Operations Research

Second Reader: David A. Schrady, Department of Operations Research

During design of the U.S. Navy's 21st Century Destroyer (DD21), Lockheed Martin is considering various measures of readiness to aid in evaluating how the ship's maintainability affects overall effectiveness. Availability, dependability and capability are all worthwhile measures of effectiveness, but do not get at the true question: "What is the probability that DD21 can "complete" some randomly arriving mission?" This thesis develops an object-oriented discrete-event Monte Carlo simulation to answer this question for DD21. Using design data from Lockheed Martin, this thesis analyzes the system effectiveness of DD21, within its Land Attack mission. Additionally, this thesis examines how drastically DD21's system effectiveness will be reduced without immediate knowledge of component failures.

DoD KEY TECHNOLOGY AREAS: Surface Vehicles, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: Modeling, Simulation, Navy, Ship, Failure, Maintenance, Availability, System Effectiveness

THESIS ABSTRACTS

EVALUATING DEMOGRAPHIC ITEM RELATIONSHIPS WITH SURVEY RESPONSES ON THE MAINTENANCE CLIMATE ASSESSMENT SURVEY (MCAS)

**Bruce R. Stanley, Jr.-Lieutenant, United States Navy
B.S., United States Naval Academy, 1993**

Master of Science in Operations Research-June 2000

Advisors: CDR John K. Schmidt, USN, School of Aviation Safety

Robert R. Read, Department of Operations Research

Second Reader: Lyn R. Whitaker, Department of Operations Research

The Maintenance Climate Assessment Survey (MCAS) was developed to proactively assess factors that contribute to a high reliability organization and strong safety climate. The 3rd Marine Air Wing (MAW), which was seeking to proactively improve its safety posture requested the assistance of the School of Aviation Safety at the Naval Postgraduate School to examine its safety climate. Previous studies of the MCAS instrument have focused on the items and their relationship to the HRO based model of safety effectiveness components: process auditing, reward system, quality assurance, risk management, command and control, and communication/functional relationships. The present effort is the first attempt to consider the relationship between item component responses and demographic item responses. It evaluates 893 maintainer responses to the MCAS from 3rd MAW and looks for measurable effects due to demographics. This study finds that the regression models constructed using the demographics as explanatory variables have very little utility in predicting scores for the components. This result allows planners the relief of using the demographics as a low priority issue.

DoD KEY TECHNOLOGY AREAS: Manpower, Personnel, and Training, Other (Aviation Safety)

KEYWORDS: Human Factors, Human Error, Accident Classification, High Reliability Organizations, Corporate Safety Culture, Naval Aviation

THE USE OF ADVANCED WARFIGHTING EXPERIMENTS TO SUPPORT ACQUISITION DECISIONS

**Kenneth W. Strayer-Captain, U.S. Army
B.S., University of Dayton, 1990**

Master of Science in Management-December 1999

Advisors: Thomas H. Hoivik, Department of Operations Research

Susan P. Hocevar, Department of Systems Management

This research effort focused on the use of Advanced Warfighting Experiments (AWEs) to support acquisition decisions. Specifically, the thesis evaluated the effectiveness of the Army Task Force XXI AWE in providing information to support investment decisions and refinement of requirements for information age technologies. A detailed analysis of the 1997 Operational Test and Evaluation Command (OPTEC) Live Experiment Assessment Report identified program developmental recommendations. Data were collected from appropriate program offices and user representatives to determine the perceived utility of the recommendations and level of implementation. Qualitative data detailing why specific recommendations were or were not implemented were used to determine the contributing factors to a program's ability to benefit from participation in the experiment. Overall, fifty-two percent of the OPTEC recommendations were reported as either fully or mostly implemented. Other potential benefits of AWE participation were identified to include: (1) marketing and exposure of program, (2) refinement of user requirements, and (3) information on integration, interfaces, and interoperability. Risks from participation in the AWE included: (1) a poor return on investment, (2) potential negative exposure, and (3) extensive changes in requirements. Recommendations to enhance the value of participation in AWEs are included.

DoD KEY TECHNOLOGY AREA: Other (Acquisition)

KEYWORDS: Advanced Warfighting Experiments, Task Force XXI, Joint Venture, Army Digitization, Acquisition Management

THESIS ABSTRACTS

FITTING LANCHESTER AND OTHER EQUATIONS TO THE BATTLE OF KURSK DATA

Turker Turkes-First Lieutenant, Turkish Army

B.S., Turkish Army Academy, 1993

Master of Science in Operations Research-March 2000

Advisor: Thomas W. Lucas, Department of Operations Research

Second Reader: Ron Fricker, RAND Corporation

This thesis extends previous research on validating Lanchester's equations with real data. The quality of the available historical data for validation of attrition models is poor. Most accessible battle data contain only starting sizes and casualties, sometimes only for one side. A detailed database of the Battle of Kursk of World War II, the largest tank battle in history, has recently been developed. The data were collected from military archives in Germany and Russia by the Dupuy Institute (TDI) and were reformatted into a computerized data base, designated as the Kursk Data Base (KDB), and recently made available and documented in the KOSAVE (Kursk Operation Simulation and Validation Exercise of the US Army) study. The data are two-sided, time phased (daily), and highly detailed. They cover 15 days of the campaign. This thesis examines how the various derivatives of Lanchester's equations fit the newly compiled database on the Battle of Kursk. In addition, other functional forms are fit. These results are contrasted with earlier studies on the Ardennes campaign. It turns out that a wide variety of models fit the data about as well. Unfortunately, none of the basic Lanchester models fit the data, bringing into question their use in combat modeling.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Combat Modeling, Lanchester Equations, Battle of Kursk

A SIMULATION OF THE JOINT TACTICAL RADIO SYSTEM BANDWIDTH REQUIREMENTS TO SUPPORT MARINE CORPS SHIP-TO-OBJECTIVE MANEUVER IN 2015

Thomas E. Turner-Major, United States Marine Corps

B.S., United States Naval Academy, 1988

Master of Science in Operations Research-September 2000

Advisor: Arnold H. Buss, Department of Operations Research

**Second Reader: William G. Kemple, Command, Control, Communications, Computers, and
Intelligence Academic Group**

The United States Marine Corps is exploring the concepts of Operational Maneuver From the Sea (OMFTS) and Ship-To-Objective Maneuver (STOM) as methods for employment of maritime forces in the future. At the same time, the Department of Defense (DoD) is pursuing the acquisition of the Joint Tactical Radio System (JTRS), a multi-band, multi-channel, multi-mode family of radios, designed to form self-organizing, self-healing communications networks. The JTRS will have to support Marine forces in combat at long distances from the forces' support and higher headquarters units. This extended range will require the use of relay radios in order to maintain connectivity between the attacking force and its support.

This thesis explores the relay station bandwidth requirements to support Marine forces. The question is analyzed through the use of a discrete-event simulation written in Java, which models the behavior of a JTRS network in a STOM scenario. Quality of service of the communication network is measured by timely delivery of messages.

The results of the simulation indicate that the JTRS network performance is insensitive to relay station bandwidth. Rather, the subordinate headquarters involved in the scenario were the most overloaded nodes in the network.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Command, Control and Communications

KEYWORDS: C4I, Simulation, Java, Object-Oriented, JTRS, STOM, OMFTS

THESIS ABSTRACTS

DYNAMIC EXPLORATION OF HELICOPTER RECONNAISSANCE THROUGH AGENT-BASED MODELING

**Craig S. Unrath-Captain, United States Army
B.S., University of North Dakota, 1990**

Master of Science in Modeling, Virtual Environments, and Simulation-September 2000

Advisors: Donald P. Gaver, Jr., Department of Operations Research

John Hiles, Modeling, Virtual Environments, and Simulation Academic Group

Patricia A. Jacobs, Department of Operations Research

This thesis uses Multi-Agent System modeling to develop a simulation of tactical helicopter performance while conducting armed reconnaissance. It focuses on creating a model to support planning for the Test and Evaluation phase of the Comanche helicopter acquisition cycle. The model serves as an initial simulation laboratory for scenario planning, requirements forecasting, and platform comparison analyses.

The model implements adaptive tactical movement with agent sensory and weaponry system characteristics. Agents are able to determine their movement direction and paths based on their perceived environment, attributes, and movement personalities. The model incorporates a three-dimensional aspect to properly simulate aerial reconnaissance. An integrated Graphical User Interface enables the user to create environments, instantiate agent propensities and attributes, set simulation parameters, and analyze statistical output.

The resulting model demonstrates the ability to represent helicopter reconnaissance behavior. It captures simulation summary statistics that illustrate enemy performance, helicopter performance, and logistical requirements. The model establishes an initial simulation tool to further explore Comanche operational requirements and planning for its Test and Evaluation phase.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Battlespace Environments, Computing and Software, Conventional Weapons, Human Systems Interface, Sensors, Ground Vehicles, Manufacturing Science and Technology (MS&T), Modeling and Simulation

KEYWORDS: Multi-Agent System, Agent-Based Modeling, Helicopter Reconnaissance, Comanche, Adaptive Behavior, Modeling and Simulation

OPTIMAL ALLOCATION OF SELECTED T-SERIES ADVANCED BASE FUNCTIONAL COMPONENT EQUIPMENT PACKAGES

**Jeffrey D. Weitz-Lieutenant, United States Navy
B.S., Purdue University, 1993**

Master of Science in Operations Research-June 2000

Advisor: Alexandra M. Newman, Department of Operations Research

Second Reader: CDR Kevin J. Maher, USN, Department of Operations Research

Advanced Base Functional Components (ABFCs) are pre-planned modular units of equipment and personnel designed to extend or create the logistic infrastructure required to support naval expeditionary operations. The ABFC program is structured to combine trained personnel with the equipment needed to perform a particular logistic mission such as seaport operations and cargo handling, warehousing, or freight terminal operations. If the ABFC must deploy to a theater of operations, individual equipment packages containing material handling equipment and/or civil engineering support equipment (CESE) vehicles tailored to the operational situation are required.

This thesis presents an optimization model that determines the minimum number and type of ABFC equipment packages required for the land-based naval logistic requirements of several hypothetical scenarios, some of which illustrate dual major theater war scenarios. The model quickly and efficiently provides the user with the minimum required number of material handling equipment and CESE vehicles for selected T-series ABFCs.

THESIS ABSTRACTS

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Operational Logistics, Advanced Base Functional Components, ABFCs, ABFC Equipment Packages, Integer Linear Programming

STATISTICAL MONITORING OF POLICE FORCE FOR RAPID DETECTION OF CHANGES IN FREQUENCY

Robert C. Weitzman-Lieutenant Commander, United States Navy

B.S.E.E., Norwich University, 1988

Master of Science in Operations Research-December 1999

Advisor: LTC David H. Olwell, USA, Department of Operations Research

Second Reader: LCDR Timothy P. Anderson, USN, Department of Operations Research

U.S. Law enforcement agencies are authorized and expected to use the minimum level of force required to maintain law and order. Few civilian law enforcement agencies and no military law enforcement agencies proactively monitor the use of force. Furthermore, agencies that do monitor force use methods that produce simplistic data summaries. These data summaries provide late and limited information to decision-makers regarding conditions sufficient to warrant managerial intervention. This study models police force incidents as a Poisson process and monitors the process to detect departures from the model. Police force data is charted using a self-starting control chart scheme. The charts assist the decision-maker in determining if intervention is necessary to correct an out-of-control condition while simultaneously minimizing unnecessary intervention when shifts in the frequency of force are plausibly due to random variation. Force data from military and civilian law enforcement agencies illustrate the methods. Methods are implemented in a Microsoft Excel spreadsheet with Visual Basic macros for ease of use.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Other (Quality Control)

KEYWORDS: Control of Excessive Force, Statistical Process Control, Control Chart Methodologies, Use of Force Modeling

AGENT-BASED SIMULATION OF MILITARY OPERATIONS OTHER THAN WAR SMALL UNIT COMBAT

Ronald F. A. Woodaman-Major, United States Marine Corps

B.S., United States Naval Academy, 1987

Master of Science in Operations Research-September 2000

Advisor: Arnold H. Buss, Department of Operations Research

Second Reader: Gordon H. Bradley, Department of Operations Research

A significant challenge to the Armed Forces today is the development of tactics, techniques, procedures, and equipment that will enable success in the small-scale combats that characterize Military Operations Other Than War (MOOTW). This thesis develops an agent-based simulation methodology for modeling MOOTW combat scenarios. The methodology combines agent-based modeling with discrete event simulation in a software package called AgentKit. AgentKit is used to model a riot control problem for an experiment that pits two kinds of tactics against two different kinds of crowds. This simulation yields insights into the scenario modeled and demonstrates the usefulness of agent-based simulation for the exploration of tactical concepts in a MOOTW context.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Agents, Modeling and Simulation, Object Oriented Programming, Java, Military Operations Other Than War, Riot Control, Peacekeeping

THESIS ABSTRACTS

AN INFINITE HORIZON ARMY MANPOWER PLANNING MODEL

Wade S. Yamada-Major, United States Army

B.S., United States Military Academy, 1989

Master of Science in Operations Research-June 2000

Advisor: Siriphong Lawphongpanich, Department of Operations Research

Second Reader: Robert F. Dell, Department of Operations Research

The Army must decide on the number of officers to access, promote, and, when necessary, separate each year. This thesis develops the Infinite Horizon Manpower Planning model (IHMP), an optimization model (based on convex quadratic programming), for managing officers in the Army Competitive Category. IHMP determines the annual numbers of accessions, promotions, and separations that best meet the desired inventory targets. In addition to operational and policy constraints, IHMP incorporates the recently implemented Officer Professional Management System XXI. Because one cannot imagine a day when the Army is not needed, the thesis regards personnel management as an infinite horizon planning problem and considers several techniques to approximate infinite time. Results from IHMP help analyze two personnel issues hypothesized by Army analysts. In one case, the Army requires the number of majors in the Operations career field to be at least 95% of its target and IHMP results indicate the number of majors in other career fields are short of their targets by as much as 30%. For the other case, IHMP outputs indicate that current inventory targets are not well aligned for a 16% reduction to the overall number of officers. IHMP analyses show how to align these inventory targets for the reduced number of officers.

DoD KEY TECHNOLOGY AREA: Manpower, Personnel, and Training

KEYWORDS: Manpower Planning, Optimization, Approximation

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